APRIL, 1959

modern castings

presents

the Official Program of the 63 d CASTINGS CONGRESS

Chicago, April 13–17

plus

the official Guide to the ENGINEERED CASTINGS SHOW

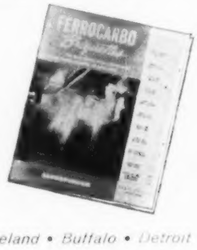
STRONGER CASTINGS FOR 300,000 TRACTORS

Farm equipment manufacturing, giant consumer of gray iron and malleable iron castings, is one of the important markets to most foundrymen. Production of farm tractors has doubled since 1945—and continues upward in excess of 20,000 units monthly.

FERROCARBO Briquettes, a patented product by Carborundum, are assisting the foundrymen in meeting these increasing production demands. They enable them consistently to make stronger, finer-grained, denser *yet more machinable castings.* Keep pace with this growing industry by making sure FERROCARBO is in your production picture.

MR. FERROCARBO®

FOR MORE INFORMATION on how you can obtain top quality in the castings that you produce, write for Form A-1497, Dept. M91, The Carborundum Company, Niagara Falls, N. Y.



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REGISTERED TRADE MARK

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modern castings

the technical magazine of the metalcasting industry

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future meetings and exhibits

APRIL

5-10 . . American Chemical Society, *Spring Meeting*. Boston.

5-10 . . *Nuclear Congress and Atom-fair*. Public Auditorium, Cleveland.

6-8 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *National Open Hearth Steel Conference*. Sheraton Jefferson Hotel, St. Louis.

6-10 . . American Welding Society, *Annual Meeting and Welding Exposition*. Hotel Sherman, Chicago.

8-9 . . Malleable Founders' Society, *Market Development Conference*. Wade Park Manor, Cleveland.

13 . . Cast Bronze Bearing Institute, *Spring Meeting*. Sherman Hotel, Chicago.

13-17 . . AFS *Engineered Castings Show* and *63d Annual Castings Congress*. Hotels Sherman and Morrison, Chicago.

16 . . National Castings Council. *Annual Meeting*. Union League Club, Chicago.

16-17 . . Magnesium Association, *Casting Section Meeting*. Congress Hotel, Chicago.

18-22 . . American Society of Tool Engineers. *Annual Meeting*. Schroeder Hotel, Milwaukee.

29-May 1 . . American Society of Mechanical Engineers, *National Metals Engineering Conference*. Hotel Sheraton-Ten Eyck, Albany, N.Y.

30–May 11 . . *32d International Fair* Brussels, Belgium.

MAY

4-8 . . American Society of Training Directors, *Annual Conference*. Sheraton-Cadillac Hotel, Detroit.

13-15 . . National Industrial Sand Association, *Annual Meeting*. The Homestead, Hot Springs, Va.

17-21 . . American Ceramic Society, *Annual Meeting*. Palmer House, Chicago.

21 . . AFS *Division Meetings, Executive Committees, Program & Papers Committees, Annual Review*. Sherman Hotel, Chicago.

22 . . AFS Technical Council, *Annual Meeting*. Sherman Hotel, Chicago.

25 . . AFS Publications Committee, *Annual Meeting*. Sherman Hotel, Chicago.

25-26 . . Malleable Founders' Society, *Annual Meeting*. The Homestead, Hot Springs, Va.

25-28 . . American Society of Mechanical Engineers, *Design Engineering Show*, Convention Hall, Philadelphia.

27-28 . . American Iron and Steel Institute, *Annual Meeting*. Waldorf-Astoria Hotel, New York.

JUNE

9-12 . . Material Handling Institute, *Exposition*. Public Auditorium, Cleveland.

11-12 . . AFS *Chapter Officers Conference*. AFS Headquarters. Des Plaines, Ill., and Sherman Hotel, Chicago.

18-20 . . AFS *Foundry Instructors Seminar*. University of Illinois, Urbana, Ill.

21-26 . . American Society for Testing Materials, *Annual Meeting*. Chalfonte-Haddon Hall, Atlantic City, N.J.

25-27 . . AFS *Penn State Foundry Conference*. Pennsylvania State University. University Park, Pa.

SEPTEMBER

24-26 . . AFS *Missouri Valley Regional Foundry Conference*. Missouri School of Mines, Rolla, Mo.

28-Oct. 1 . . Association of Iron and Steel Engineers, *Annual Convention*. Sherman Hotel, Chicago.

OCTOBER

2-3 . . AFS *Northwest Regional Foundry Conference*. Benjamin Franklin Hotel, Seattle.

3-10 . . International Committee of Foundry Technical Associations, *International Foundry Congress*. Madrid, Spain.

7-9 . . Gray Iron Founders' Society, *Annual Meeting*. Fairmont Hotel, San Francisco.

8-9 . . AFS *Michigan Regional Foundry Conference*. Pantlind Hotel, Grand Rapids, Mich.

16-17 . . AFS *New England Regional Foundry Conference*. Massachusetts Institute of Technology, Cambridge, Mass.

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Accurate casting of this 40-lb. rear end housing cuts machining at Auto Specialties.

Quality Controlled HANNA SILVERY... Simplifies Consistent Production of Quality Controlled Castings at Auto Specialties

Much of Auto Specialties Manufacturing Company's fine reputation has been built on the high quality malleable castings produced in huge quantities at its St. Joseph, Michigan, foundry. An important factor in this continuous high quality story is the use of Hanna Silvery. Its dependable analysis plays a major role in the close silicon control of cupola-electric furnace duplexing of malleable, so necessary in the manufacture of precision automotive parts.

Whether they are housings or gears, sprockets, universal joints or clutch plates, quality controlled Hanna Silvery is of vital assistance in maintaining the exacting chemical composition necessary to production of precision castings time after time. This record is substantiated by a million-volt X-ray machine, a part of Auto Specialties quality control system, which spot checks castings for uniformity and accuracy.

Hanna produces high quality pig iron for every foundry need. All regular grades, plus close-grain HannaTite, are available in 38-pound pigs and HannaTen ingots. Trained representatives are ready to help with your metallurgical problems. For assistance, call Hanna today.

Circle No. 152, Page 167-168

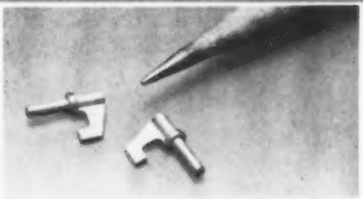
Millions of perfect castings at Auto Specialties pass under the eye of this X-ray machine.

THE HANNA FURNACE CORPORATION
Buffalo • Detroit • New York • Philadelphia
Merchant Pig Iron Division of
NATIONAL STEEL CORPORATION

HANNA
THE BEST KNOWN NAME IN IRON

the editor's report

by Jack Schaum



■ **Ever wonder what the size limitations** are on metalcasting processes? Here are two contenders for the world's record. On the left we have the world's heavyweight contender . . . a 250 ton steel rolling mill housing cast by Bochumer Verein in Germany. And in the opposite corner we have the world's smallest casting measuring only 0.200 in. in overall length with the flag portion a mere 0.045 in. thick . . . produced in silicon-manganese tool steel by Casting Engineers of Chicago. Anyone wishing to challenge these two records just send your evidence to the MODERN CASTINGS Editor.

■ **Could your foundry have used $600,000 more profit** in the past six years? Would you like your management staff and hourly workers systematically searching for possible ways to reduce costs in your operations? If the answer is "yes," then you should take a close look at the Work Simplification program that netted this remarkable result for Texas Foundries, Inc., Lufkin, Texas. Watch MODERN CASTINGS for the details.

■ **Record-breaking Shaw Process casting** . . . weighs 6000 lb. Hica Inc., Shreveport, La., made this precision 4130 cast steel die for injection molding of plastics.

■ **The aircraft industry** keeps moving the goal posts on the metalcasting industry. Par for their course now is castings accurate to ±10 thousandths of an inch on critical dimensions and 125 RMS finish on critical surfaces. If foundrymen can improve their casting accuracy by 0.005 in., they can save the difference, in one case, between $70 (the as-cast price of the casting) and $1200 (the cost of machining the last 0.005 in. from critical areas) . . . And then there's the aluminum wave guides being cast with 0.075-in. wall thickness for Westinghouse.

■ **High speed computers** can help you select the most economic combination of furnace charge materials for every day's operation! If a computer is not available, manual techniques are also explained in a 1959 Castings Congress Paper by Gideon I. Gartner, Watertown Arsenal. Scheduled for publication in MODERN CASTINGS soon, the article tells foundrymen about a linear programming technique that helps choose the most feasible raw material combination with the minimum cost. You can calculate optimum prescriptions for individual heats and determine which materials to buy for inventory.

■ **Wear on mating surfaces of tight flasks** . . . has practically been eliminated by molding a **thin rubber strip** on the flask-bearing surface of match plates. Inventor, Richard L. Olson, says the cushioning effect of this rubber also **stops** the **noise** generally attributed to metal-metal contact in jolt-squeeze molding.

■ **One pound of weight** . . . saved on a casting in a **ballistic missile** adds 18,000 ft to its range! And a pound saved in the third stage rocket of a space vehicle reduces fuel requirements by 1000 lb!

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and *Dixie Bond*. If you missed that issue, let me know and I'll send you a reprint (Note: We have ordered 1000 extra reprints per month to meet the increasing demand.)

Our sermon today applies equally to all three clays and therefore, to every practice—including yours. Although it is a general discussion and cannot be universally applied, it will stand up in most cases.

In brief (and within reason), the more clay or the stronger the sand, the better. (High strength is more than 14 psi; low strength is generally below 10 psi. In between are the middle-of-the-roaders or special cases.) The merits of high-strength sands are meeting wider acceptance now — for which Eastern Clay Products is grateful. More and more, the following truths appear in print:

1. High-strength sands give higher mold hardness.

2. Cuts, washes, rat-tails and scabs are reduced by increasing clay (at temper, of course).

3. High-strength sands *improve* finish.

4. High-strength sands require less combustible material.

5. At proper temper, high-strength sands produce castings closer to proper weight and dimensions.

6. High-strength sands provide for less metal penetration and mold-wall movement.

7. Tempered to equal deformation, a high-strength sand may show *higher* flowability.

What has this to do with additives? Simply this. Weak sands may need additives to cure their basic faults, but this is not the only use of an additive. Furthermore, using additives to overcome the weakness of low clay is not economical practice. Startling or otherwise, high-strength sands require less additives than weak sands. And when used with such sands, the purpose of the additive can hardly be described as "medicine."

Let's try a medical comparison. A healthy adult requires less than five mg of Vitamin B_1 per day to stay "bright-eyed and bushy-tailed." This may be obtained from the normal diet or supplemented by pills. In either case, the B_1 is a basic food requirement of the human body. But to cure a bad hang-over, a doctor may give 20,000 units of B_1 — about an 11-year supply at typical food levels. So the same substance is either a food or a medicine, depending on the condition of the user.

By the same token, the user of high-strength green sand uses additives to keep his daily cast "bright-eyed and bushy-tailed." They help him make better looking, more saleable castings . . . keep his scrap and overall costs to a minimum. He ships castings that are close to dimension and proper weight. And, everything else being equal, he makes more money.

In our future discussions of additives, we will stress this "food" approach. Our angle? That's easy. We know our future lies in the future success of our customers. We want to help you *sell* more castings by making better ones at lower cost through improved practice. Our policy: to charge only for our product but to deliver "product plus" —

- plus service
- plus research
- plus know-how
- plus impartial help on sand problems

Please let us know when and how we can be of help. Drop a line, or give us a call.

high pressure molding machine

"Give us a flask large enough and we'll squeeze a pattern as big as a battleship." That's the word from Taccone Pneumatic Equipment Co., where the largest high-pressure molding machine was designed and built for pipe fittings and cast iron boiler systems.

Heard the facts about the uniform molds, elimination of ram-offs and long list of cost savings offered in these machines? Write—we'll be glad to go into detail.

VITAL STATISTICS

Squeeze pressure at 80# line	672,000#
Actual squeeze time for ramming a mold with 7000# of sand	6 seconds
Flask size	84" x 84" x 16" (or 2 flasks 42" x 84" x 16")
Line pressure	80 to 100 psi
Total squeeze pressure at 100# line pressure	705,600#

Creators of Living Minerals

International Minerals Chemicals

EASTERN CLAY PRODUCTS DEPT.

INTERNATIONAL MINERALS & CHEMICAL CORPORATION

Administrative Center, Old Orchard Road, Skokie, Illinois • ORchard 6-3000

21-59

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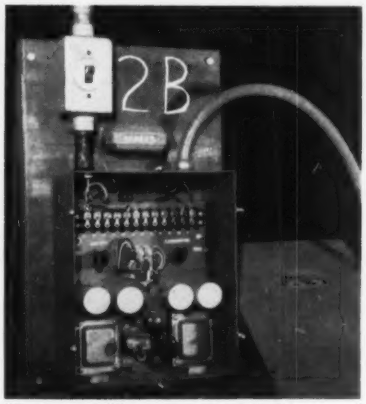
Electronic Mold Counter is Backbone of Incentive Plan

■ A unique electronic mold-counting device is being used in conjunction with an incentive plan for the molding and pouring lines at Crouse-Hinds foundry, Syracuse, N. Y.

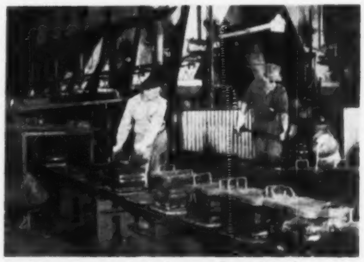
A separate count of castings poured was necessary for each of four pouring loops; and this presented a problem. Simply registering the number of molds passing a point on the loop proved ineffective. This system counted every mold passing the counter, whether it had been poured off or not. In event that a mold made the loop twice, it was counted twice. Starting the molding line in the morning or after breaks confused the count.

Company engineers solved the problem by installing electronic counting devices in the top of the cooling hoods for each molding line. These



Electronic mold counter is installed in top of the mold cooling hood and activated by heat from mold sprues.

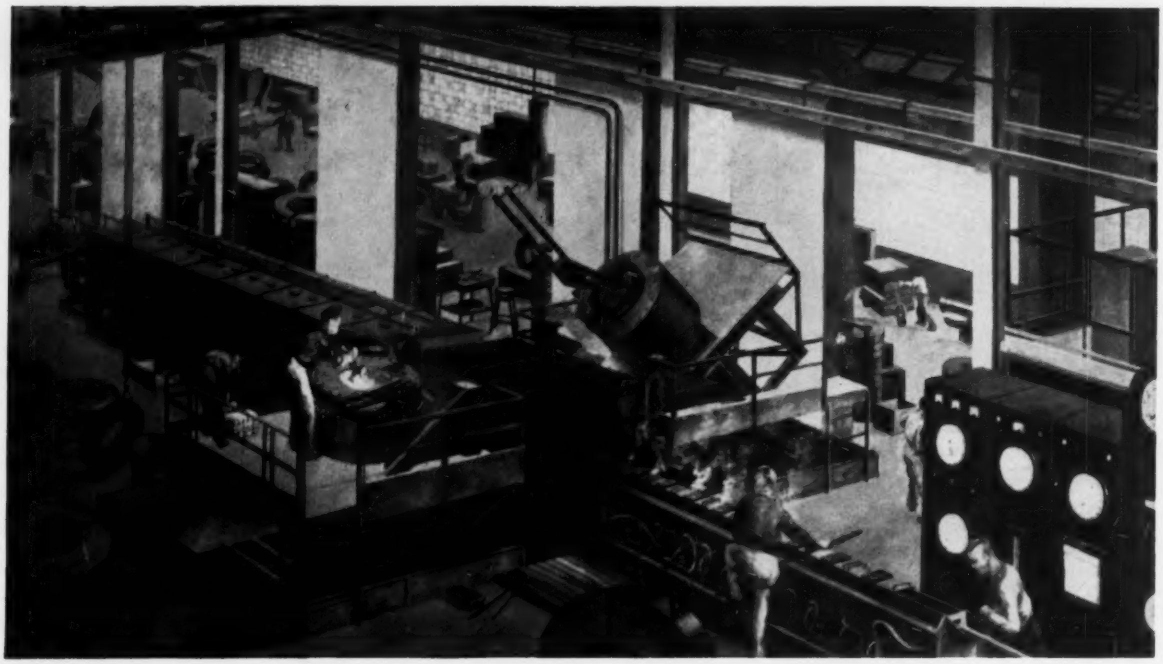
devices utilize a photo-cell unit activated by heat from mold sprues. Engineers connected each photo-cell to an amplifier which strengthened the signal to register each newly-poured



Counter in top of the cooling hood at left registers only the molds that have just been poured on the loop.

casting on a counter. The unit may be adjusted to varying sensitivities of heat radiating from the sprue.

Crouse-Hinds officials state that the electronic counters are accurate to one per cent.



60 CYCLE INDUCTION MELTING OF HIGH LEADED BRONZES

15 years ago, THE CLEVELAND GRAPHITE BRONZE COMPANY, division of CLEVITE CORPORATION, pioneered 60 CYCLE INDUCTION MELTING of bronzes with up to 35% lead. Special furnaces developed by AJAX for this difficult job are an important element in their unique continuous production line for steel-backed bronze bearing strip. 60 CYCLE INDUCTION MELTING furnaces resulted in substantial improvements and cost savings over gas-fired units used earlier for that purpose. Today, CLEVITE operates six continuous lines in this country and abroad with AJAX 60 CYCLE INDUCTION MELTING furnaces, producing enough strip to make 130 million bearings and bushings per year.

The heavy duty 60 cycle inductor developed by AJAX and pioneered by CLEVITE will attain a lining life of one year with bronzes of substantial lead content. Electromagnetic stirring assures uniform alloy and close temperature control. Compared to externally fired equipment, metal loss savings run into many thousands of dollars per year. Recently, several large producers of leaded bronze castings converted their foundries entirely to 60 CYCLE INDUCTION MELTING.

While this is one of the most difficult metals to handle, the advantages of 60 CYCLE INDUCTION MELTING stand out today wherever copper alloys are melted. As specialists in 60 CYCLE INDUCTION MELTING, we have developed furnace types to best fill each application.

AJAX USA

ENGINEERING CORPORATION

TRENTON 7, NEW JERSEY

60 CYCLE INDUCTION MELTING

Associated Companies: Ajax Electrothermic Corporation Ajax Electric Company

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Circle No. 216, Page 167-168

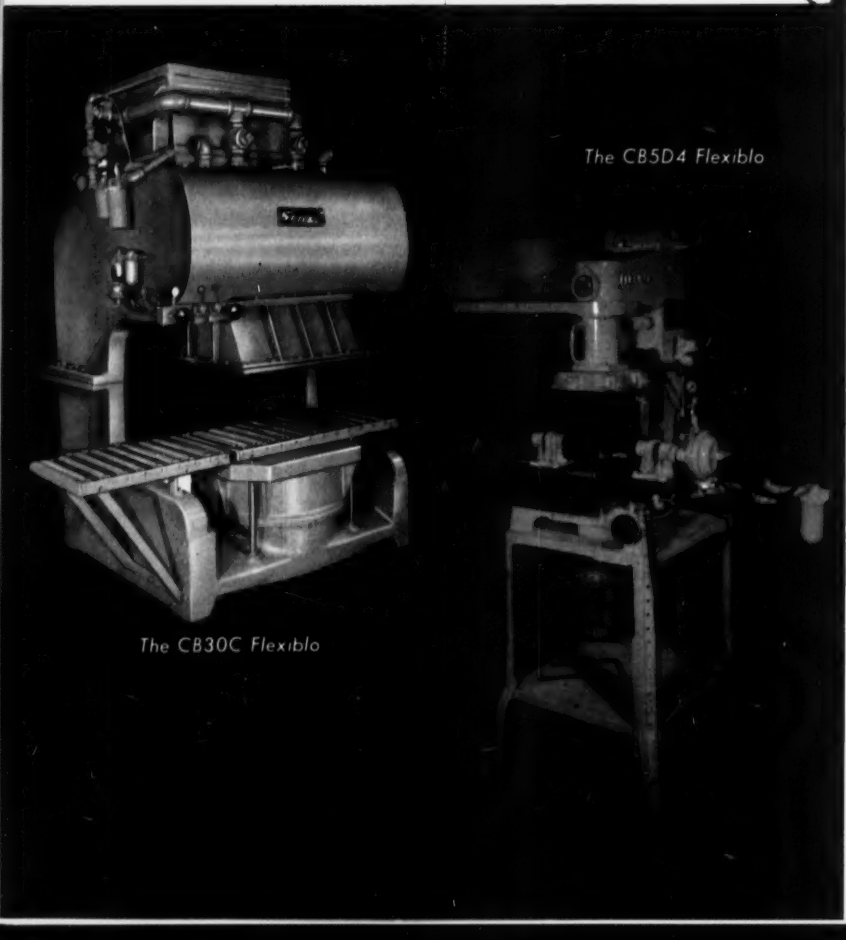
DEVELOPMENTS FROM THE B&P TECH CENTER

A Size and Type of Coreblower for Every Practical Need (CO_2 TOO)

Product expansion and development in the coremaking field now permit B&P to offer a unit to meet every coreblowing requirement. Outstanding units for jobbing or repetitive production of shell, CO_2 or conventional cores are available in a complete range of sizes, to meet every need.

1. For tiny pin cores and up to 400 pound cores.
2. For wooden, metal, metal-reinforced or plastic core boxes.
3. For vertically-split horizontally-split or open core boxes.
4. For all conventional, shell and CO_2 core sands.
5. For high strength and special core sands requiring agitator.
6. For full pressure blow, Pulsator blow or Low Pressure Prefill with blow.
7. For applications requiring quick-change or universal blow and vent plates.
8. For every CO_2 blowing requirement . . . (a complete line of Flexigas gassing units also available).

And a complete line of accessories including Rol-A-Draw and Rol-A-Cor core rollover-draw units.



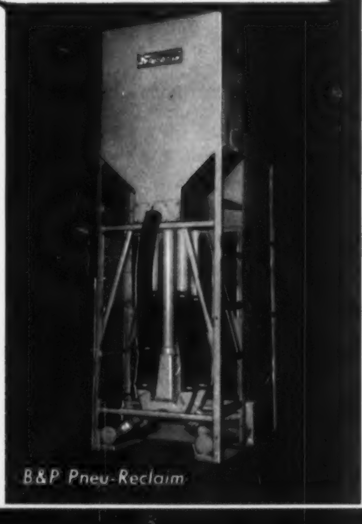
The CB5D4 Flexiblo

The CB30C Flexiblo

A Compact, Inexpensive Dry Sand Reclamation Unit for All Sands

There are important reasons for the foundry industry's acceptance of Pneu-Reclaim dry sand reclamation units by a 3-to-1 margin over all other units. These reasons permit gray iron, steel and non-ferrous foundries to obtain impressive savings, and to retain the full benefit of savings through minimum operating and maintenance costs.

1. Only Pneu-Reclaim has been thoroughly proved for the reclamation of every type of sand—conventional backing, facing and core sands, as well as CO_2, shell and air-setting sands . . . proved at the B&P Tech Center and in the field.
2. Only Pneu-Reclaim—with exclusive Dual-Jet Scrubbing—operates at half the air pressure (and half the power consumption) of other units.
3. Only Pneu-Reclaim has exclusive B&P Level Flow—makes it more compact with much lower overall height—installs easily in many areas where other units won't fit.
4. Only Pneu-Reclaim offers higher capacity—per square foot of area or per dollar invested.
5. Pneu-Reclaim maintenance costs are less than half those of any other unit.



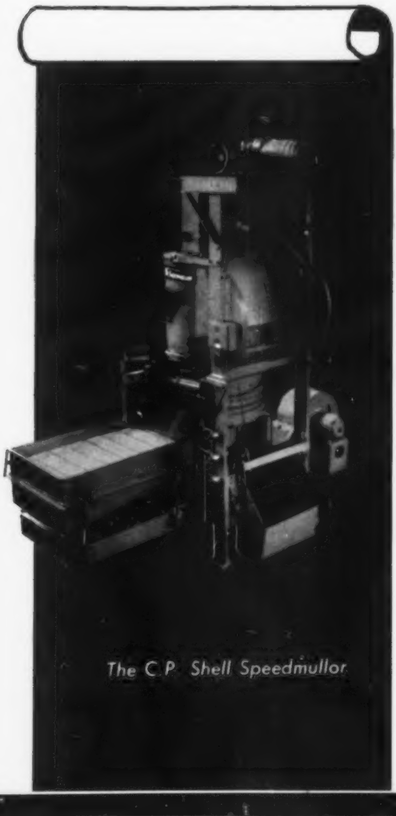
B&P Pneu-Reclaim

Shell Sand Processing Equipment Proved for Every Application

Hot process, warm process and cold process Shell Speedmullors all benefit from the extensive research and development work carried on at the B&P Technical Center. As a result of this work—carried on with the co-operation of leading resin and sand manufacturers—the capacity and performance of shell sand Speedmullors have been greatly increased.

In one series of tests utilizing preheated sand in a hot process Shell Sand Speedmullor, processing capacity has been increased over one hundred per cent.

The B&P line of Shell Sand Speedmullors provides the industry with by far the broadest and most flexible coating equipment available for shell sand processing. Seven different sizes in hot, warm and cold process units assure a coating unit to meet every requirement, under every operating condition. Capacities to 27,000 pounds per hour.



The C.P. Shell Speedmullor

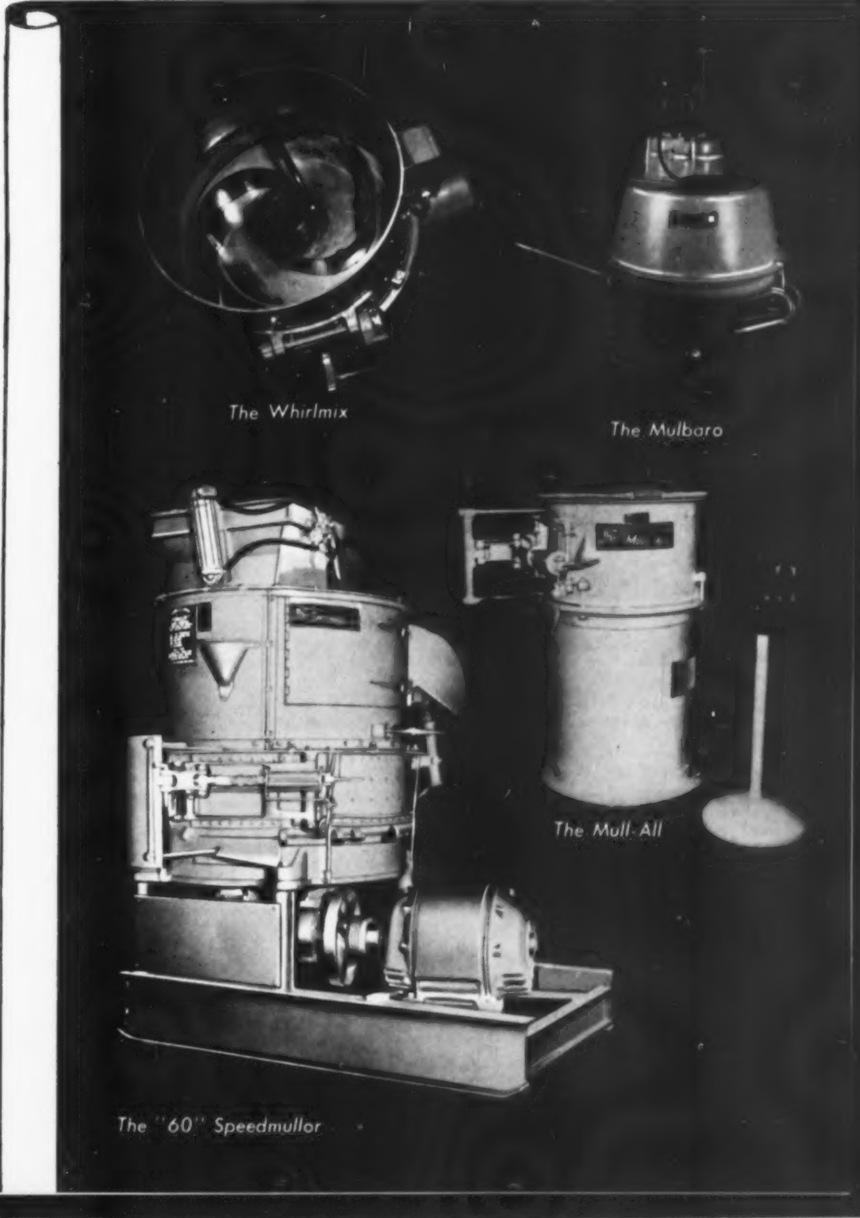
The Broadest Line of Mulling Machinery Ever Offered

In the field of molding and core sand preparation, the expansion of the Beardsley & Piper line of mulling machinery, with the addition of the Whirlmix and the Mull-All, now provides the most complete line for all applications. The Mulbaro remains the only truly portable mulling unit. Its overall application to molding and core sand preparation is combined with its true portability and low cost to provide unbeatable advantages in its field.

Available in two sizes, the compact and flexible Whirlmix is ideal for core sand preparation. It is especially suitable for the new CO_2 and air-setting core sand mixtures. Its low cost makes it an excellent investment for the foundry entering these fields.

The new Mull-All is the only small muller that offers the quality and ruggedness advantages of big production unit construction. Its capacity, performance and thoroughness of mixing are well ahead of other small units.

The advantages of the Speedmullor line—including six units with capacities to 76 tons per hour of thoroughly mulled sand—are well known. Speedmullors alone offer *rubber-to-rubber mulling, complete aeration during mulling, mulling in suspension, complete cooling during the mulling cycle,* and mulling cycles at least *three times faster* than any other unit.



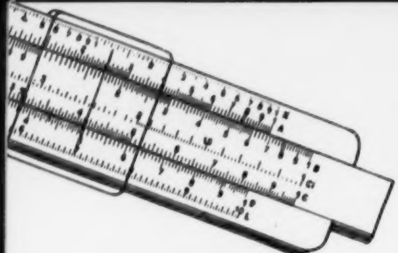
The Whirlmix

The Mulbaro

The Mull-All

The "60" Speedmullor

B&P Pneu-Reclaim



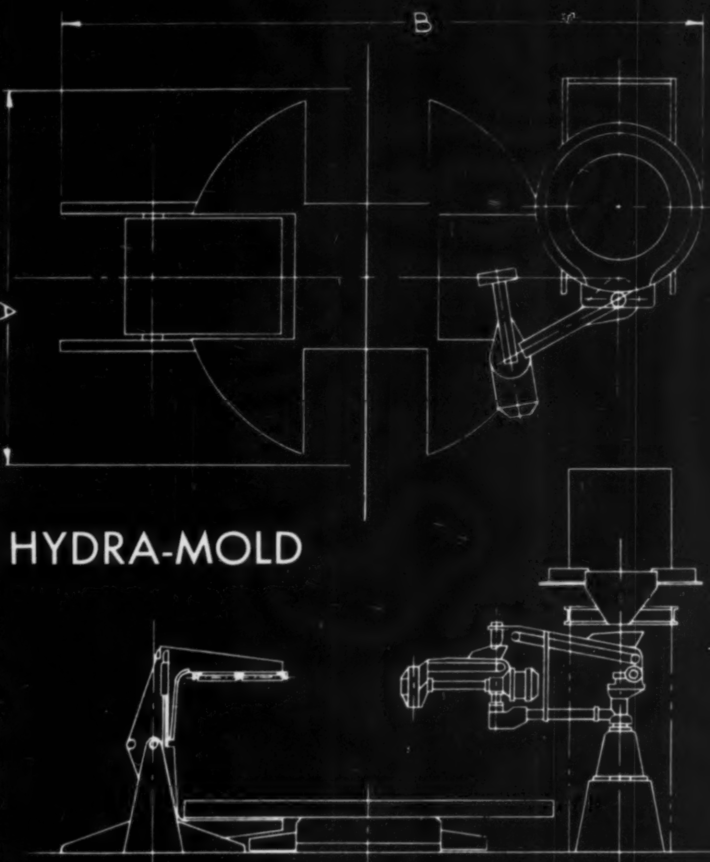
A Highly Productive — Yet Fully Flexible Complete Molding Unit — Without Pits

The new Hydra-Mold is the culmination of Beardsley & Piper efforts to develop the most compact production or jobbing molding installations. It incorporates all-hydraulic Roto-Mold, Rol-A-Draw and Hydra-Slinger. A single, low-cost hydraulic unit is used for the entire Hydra-Mold. Here is the unit that makes production work faster and more accurate than ever before—that permits jobbing work to be handled like production work.

These units offer production equivalent to—or greater than—that obtained from four large fully rigged molding stations. Yet, costs are reduced because sand is delivered to a single point of use, the Hydra-Slinger. Although the foundry has all of the flexibility of four separate stations, a single rollover-draw machine is needed. Because separate molding operations are performed at separate molding stations around the Roto-Mold Table, even miscellaneous jobbing work can be handled like repetitive production work. There's real production flexibility, too, with four patterns run simultaneously—any size work, any height molds within the range of the unit can be handled without slowing the operation. Pattern changes can be made instantly—without downtime.

This is the unit that keeps costs in line regardless of the level of operation. As few as two men or as many as six men can be assigned to the unit, depending on the production required. Best of all, there are no pits required—the entire unit is installed above-floor level. Only the B&P Hydra-Mold offers all of these advantages.

HYDRA-MOLD



**Roto-Mold Diam. "A"	*Rol-A-Draw Model	Length "B"	Max. Weight of Flask, Pattern & Sand	***Flask Size	Max. Draw
14′0″	2022H	25′0″	2000 lb.	36″ x 56″	20″
16′0″	4025H	28′0″	4000 lb.	40″ x 66″	23″
16′0″	6030H	28′0″	6000 lb.	48″ x 72″	28″
18′0″	9030H	30′0″	9000 lb.	53″ x 84″	27″
18′0″	12032H	31′0″	12000 lb.	54″ x 90″	28″
18′0″	15032H	31′0″	15000 lb.	54″ x 90″	27″

*Roto-Mold—Rol-A-Draw combinations to meet typical requirements. Other combinations may be recommended for specific conditions.
**Four, six, or eight station available.
***Normal flask size shown for four station Roto-Mold.

FOREMOST DEVELOPER OF FOUNDRY MACHINERY

SANDSLINGER • SPEEDSLINGER • HYDRA-SLINGER • SPEEDMULLOR • PREPARATOR • SPEEDMULLOR-PREPARATOR UNIT • SHELL SPEEDMULLOR • MULL-ALL • MULBARO • LAB MULBARO • PNEU-RECLAIM • FORMATIC SHELL MOLD UNIT • CORMATIC SHELL CORE UNIT • FLEXIBLO • SAN-BLO • WHIRLMIX • ROL-A-DRAW • ROTO-MOLD • ROTO-FEED • HYDRA-MOLD • BEEP • SKIPTROL • MULLTROL • MULLTROLMATIC • BLOMATIC • CORMATIC • NITE GANG • MAGNARATOR

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2424 N. Cicero Avenue
Chicago 39, Illinois

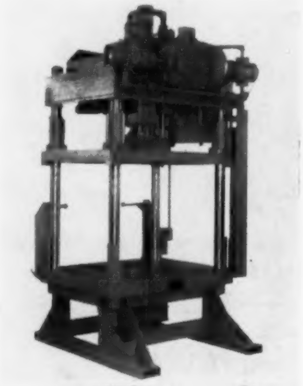
Build an idea-file for improvement and profit. The post-free cards on *the last page* will bring more information on these new . . .

products and processes

STRAINER CORES . . are available in standard or custom-made shapes to duplicate drawing or sample. Producer states this product, made of silica sand and heat-resistant binder, is extra hard. *Rudow Mfg. Co.*
For Manufacturer's Information
Circle No. 1, Page 167-168

BLASTING CABINET . . . features two independent ceramic-nozzled blast guns for clearing small articles, crevices, angles and heavy castings. *Cyclone Sandblast Equipment Co.*
For Manufacturer's Information
Circle No. 2, Page 167-168

TRIM PRESS . . . for trimming castings by high-speed hydraulic action. Thirty-



five ton press. *B & T Machinery Co.*
For Manufacturer's Information
Circle No. 3, Page 167-168

NEW TUMBLING MEDIA . . . claimed to offer up to 10 times the useful life of conventional materials. Shapes suitable to meet specific needs, materials can be used without tumbling solutions. *Dixon Sintaloy Inc.*
For Manufacturer's Information
Circle No. 4, Page 167-168

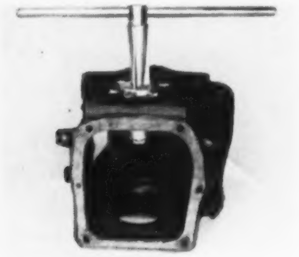
FIRE-RESISTANT . . . hydraulic fluid minimizes danger in case hydraulic lines serving die-casting machines break. *Celanese Corp. of America, Chemical Div.*
For Manufacturer's Information
Circle No. 5, Page 167-168

MEASURES THICKNESS . . . of coatings and platings on base materials. Non-destructive measurement instrument determines thickness of metallic film or foil and detects surface and subsurface cracks in smooth and rough coatings on castings. *Gulton Industries.*
For Manufacturer's Information
Circle No. 6, Page 167-168

EXPANSION BOLT . . . claimed to allow assembly of two or more castings

without necessity of tapping holes in the castings. *Kirel Inc.*
For Manufacturer's Information
Circle No. 7, Page 167-168

KNURLING TOOL . . . rehabilitates worn castings by raising the metal in



the bore. Guides fit all diameter bores up to 12 in. *Peerless Tool Co.*
For Manufacturer's Information
Circle No. 8, Page 167-168

HAND CUTTING TORCHES . . . injection-type, feature smooth gradual oxygen flow. *Air Reduction Sales Co.*
For Manufacturer's Information
Circle No. 9, Page 167-168

SAFETY TONGS . . . said to eliminate spills in case crucible cracks. Tongs

Continued on page 18

products and processes

Continued from page 16

grasp crucible around base. Use circle number for more information. *Inductotherm Corp.*

For Manufacturer's Information Circle No. 10, Page 167-168

PORTABLE HARDNESS TESTER . . . for testing castings inaccessible to bench-type hardness testers. Two models: 4-1/2 and 12-in. diameter or thickness capacity. *Riehle Testing Machines.*

For Manufacturer's Information Circle No. 11, Page 167-168

AIR-POWERED DRILL . . . for close corner work weighs 5 lb and reportedly produces increased power on less air. Drilling capacity, 9/16-in.; reaming and tapping, 3/8-in.; 450 rpm. *Thor Power Tool Co.*

For Manufacturer's Information Circle No. 12, Page 167-168

STATIONARY AIR COMPRESSOR . . . delivers up to 835 cu ft of air per min at 100 psi. *Atlas Copco.*

For Manufacturer's Information Circle No. 13, Page 167-168

TORCH BURNERS . . . reportedly offer 10 to 1 turndown without sacrifice of flame stability. No air blower required. *Bryant Industrial Products Corp.*

For Manufacturer's Information Circle No. 14, Page 167-168

FIVE FERROALLOYS . . . in crushed form are now packaged in pre-weighed bags. Eliminates weighing and handling of loose material. *Electro Metallurgical Co.*

For Manufacturer's Information Circle No. 15, Page 167-168

PROTECTIVE CLOTHING . . . made of aluminized rayon reportedly offers added strength and heat resistance. *Wheeler Protective Apparel, Inc.*

For Manufacturer's Information Circle No. 16, Page 167-168

SOLID FILM LUBRICANT . . . reportedly greatly increases wear life of moving parts operating in oil or grease. *Electrofilm Technical Service.*

For Manufacturer's Information Circle No. 17, Page 167-168

VERNIER SCALE MAGNIFIER . . . provides sharp enlargement of scale lines for more exact readings. Includes two magnets embedded in base for attaching to metal scales. *Bausch & Lomb Optical Co.*

For Manufacturer's Information Circle No. 18, Page 167-168

CARBON BRICK . . . and other shapes made by automated process that cuts production time from weeks to minutes. Claims higher quality carbon. *National Carbon Co.*

For Manufacturer's Information Circle No. 19, Page 167-168

DUCTILE BY PLUNGE . . newest technique for producing ductile iron is said to be plunging a refractory basket containing magnesium additive into a ladle of iron. Method is said to eliminate flame and smoke, lower treating cost, and produce cleaner iron. Package designed for method contains weight of alloy needed for treatment of specific

ladle size. *Ohio Ferro-Alloys Corp.*

For Manufacturer's Information Circle No. 20, Page 167-168

SHUT-OFF GATES . . . for conveyors handling sand, coke and stone said to provide trouble-free operation. Features self-cleaning double rack. *Beaumont Birch Co.*

For Manufacturer's Information Circle No. 21, Page 167-168

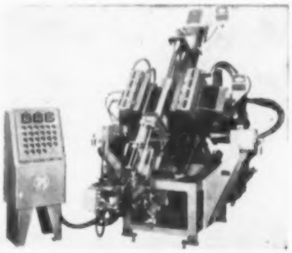
HEAT-TREATING FURNACE . . . salt bath type, operates at temperatures of 1750-2350 F. Used for treating precision metalworking tools made of high-carbon high-chrome and air hardening steels. *A. F. Holden Co.*

For Manufacturer's Information Circle No. 22, Page 167-168

DRY FILM LUBRICANT . . . supplied in 11.5-ounce hand aerosol bombs. Non-flammable colloidal graphite reported to lower interfacial tensions with oils and to cause frictional surfaces to retain thicker oil films. *Miracle Power Products Corp.*

For Manufacturer's Information Circle No. 23, Page 167-168

CORE MANDREL . . . attachment for company's single station automated core machine reportedly provides close con-



trol of core wall thickness and exceptional uniformity of cure. *SPO, Inc.*

For Manufacturer's Information Circle No. 24, Page 167-168

DIE ASSEMBLIES . . . for zinc and aluminum die-casting enables diecaster to replace cavities at minimum cost in minutes. *Detroit Mold Engineering Co.*

For Manufacturer's Information Circle No. 25, Page 167-168

INDIRECT ARC FURNACE . . . features roll-over arrangement with mold clamp attachment enabling precision investment mold to be clamped directly over pouring hole in furnace barrel. *British Industries Corp.*

For Manufacturer's Information Circle No. 26, Page 167-168

CO_2 SHELL MOLDS . . . combines close-tolerance aspects of shell molding with time, labor and equipment saving features of CO_2 process. *National Cylinder Gas Co.*

For Manufacturer's Information Circle No. 27, Page 167-168

WATERLESS MOLDING SAND . . producing high-precision castings is possible with use of new sand binder. Dry binder is used with mix of 120 to 190 gfn sand, oil and a catalyst. Principal advantages are said to be reduction in gas on pour-off and use of finer sands;

principal disadvantage is said to be higher initial cost of low clay content sand used. *Archer-Daniels-Midland Co., Federal Foundry Supply Div.*
For Manufacturer's Information Circle No. 28, Page 167-168

AUTOMATIC SAND COOLER . . . designed to rapidly reduce the temperature of sand while in transit from shakeout to storage bin. Adds water to shakeout sand at controlled rate. *Harry W. Dietert Co.*
For Manufacturer's Information Circle No. 29, Page 167-168

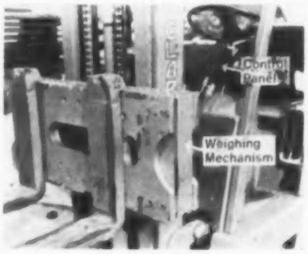
ELECTRIC-POWERED SHOVEL . . . incorporates system controlled completely by operator's thumb. Offered with

selected speeds and variety of steel scoops. *Munson Mill Machinery Co.*
For Manufacturer's Information Circle No. 30, Page 167-168

TUBE FILING SYSTEM . . . for rolled prints, charts, drawings, maps, etc. in enclosed units of four tubes per roll file. Two tube lengths: 27 and 33 in. *Plan Hold Corp.*
For Manufacturer's Information Circle No. 31, Page 167-168

HARD FACING WELDING . . . alloy designed for hot work applications. Reportedly will not chip or spall under most severe service. *Crucible Steel Co. of America.*
For Manufacturer's Information Circle No. 32, Page 167-168

WEIGHING MECHANISM . . . attachment for fork lift trucks said to be accurate to two-tenths of one per cent



of capacity. Available for company's 3000, 4000 and 5000-lb trucks. *Clark Equipment Co.*
For Manufacturer's Information Circle No. 33, Page 167-168

PORTABLE PYROMETER . . hand-type unit is said to be remarkably rugged and economical. *West Instrument Corp.*
For Manufacturer's Information Circle No. 34, Page 167-168

WOOD SURFACING . . . tool designed

Continued on page 22

products and processes

Continued from page 20

to achieve better standards of craftsmanship in patternmaking. Utilizes three high-speed steel cutters to eliminate possibility of "grab" or "kick-back," according to manufacturer. *Clifford A. Kroening, Inc.*

For Manufacturer's Information
Circle No. 35, Page 167-168

product report . . .

Shakeout costs were cut over 60 per cent by using a 2500-lb capacity fork-lift truck (manufactured by Beardsley & Piper Co., Chicago) at Crawford & Doherty Foundry Co., Portland, Ore.

The foundry had employed three overhead cranes to move molds to shakeout and return empty flasks to a conveyor. Maintenance on the floor-controlled cranes was reported to be extremely high. The entire shakeout operation involved six men for a complete eight-hour shift each night.

A fork-lift truck was purchased to handle these molds and flasks. The

time needed for this job has been cut from 48 man-hours to 18. An important item of crane wear has been eliminated, and crane maintenance reduced. This truck is further used to move castings from the shakeout to stress-relieving furnace or to cleaning room.

Pneumatic tires on the truck take the shock out of travel over rough foundry floors. The Crawford & Doherty plant uses the truck to transport cores from the core room to molding floors. Company officials report that soon, with a few changes in core room layout, the foundry will use their truck to move all large green cores to oven racks.

In two years of operation in this foundry, repair parts have been limited to spark plugs, ignition points, fan belt, filter elements and gaskets. Company officials state that total costs, including gas and oil, have been less than $400, with no crew downtime chargeable to the truck.

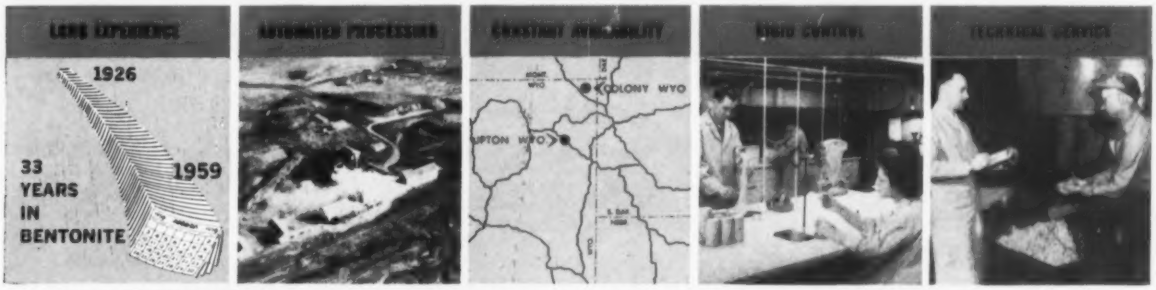
For Manufacturer's Information
Circle No. 36, Page 167-168

Circle No. 165, Page 167-168

DEPENDABLE GREEN BOND

means
smoother cleaner
more accurate
castings
ALL THE TIME!

5 Good reasons why foundries rely on GREEN BOND



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Technical Bulletin

Archer-Daniels-Midland company
FEDERAL FOUNDRY SUPPLY DIVISION
2191 West 110th Street • Cleveland 2, Ohio

Circle No. 165, Page 167-168

the SHAPE

safety, hygiene,

Salmagundi

A Pain in the Back is . . .

I still receive inquiries about detecting malingering where "back cases" are concerned and, frankly, I don't know how one can tell if a back injury is real or faked. For example, I think my boss's back pains are real; I've seen him walk with a 10 degree list when he couldn't have possibly known that anyone was watching. (Anyway he'd scorn compensation.) In my own case, I twisted my back picking up a 10-lb baby crib and was practically immobilized for three days. (Mine happened off the job and I couldn't collect.)

On the other hand, I know of a case where the foundry paid permanent partial disability to a molder for a long time. But the molder's avarice exceeded his guile. You see he forgot to tell the newspaper men when they wrote him up as the champion bowler in a delightful city of New York State. He now has his newspaper clippings but no further compensation checks.

The Daily Double

A brass foundry in Newark, N.J., never bothered with pre-employment physical examinations . . . . so one day the owner hired a man. After one year's employment the man filed a claim for silicosis. The owner moaned and told his plight to a neighboring foundryman. During the discussion it developed that the same man previously sought employment with the neighbor. But the neighbor had a pre-employment physical-examination-program. His plant physician's pre-employed examination disclosed that the man already had silicosis.

A letter to the former employer brought the response that the man had contracted silicosis in a Pennsylvania mine and was already receiving compensation under Pennsylvania's Workmen's Compensation Act. Our man wanted to collect in two states. Caveat emptor!

Now Hear This!

Occupational loss of hearing is now a problem confronting all industry . . . .

# of things

air pollution

by Herbert J. Weber

. . . a Pain in the Neck!

not just foundries! But here is a new twist. We all know sand hoppers jam with moist sand and the remedy for relieving the bridging has been: (1) balloon liners, (2) electric vibrators, (3) pounding hell out of the hopper with a mallet, crow bar or any tool which will effectively dent the hopper so that it will be in relief over intaglio, depending on whether you're looking at the inside or outside.

In one foundry using electric vibrators, the men turned off the vibrators and substituted remedy (3) because the vibrators were too noisy and the pounding noise was in the low frequencies. It is admitted that remedy (3) is quite expensive.

In my researches, I have uncovered the following effective remedy:

(1) Smooth hopper walls. If new, skip step (1).

(2) Spray the hopper walls with epoxy resin.

(3) Apply a graphite-resin paint. I am told this treatment will last one to two years and will eliminate bridging.

Physician Heal Thyself

At the National Conference on Air Pollution, I attended a session on the effects of air pollution on health. Statements were made that there is a definite connection between lung cancer and air pollution.

The relationship has never been proved but has long been suspected. The suspicion arises from the fact that mortality rates for lung cancer among city dwellers are considerably higher than for those among rural groups; also from the evidence that many pollutants found in city air are known to produce experimental cancer in animals.

During the session, some of the physicians who feared the effect of air pollution on their lungs, were enjoying a cigarette . . . without filters yet! The session room looked like the London fog. I went outside to the industrial district to get a breath of cleaner air.

let's get personal

J. A. Ackermann . . . has been named sales manager, and **J. A. Draxler,** chief engineer, Elwell-Parker Electric Co., Cleveland. Ackermann, formerly chief engineer, has been with the company since 1923. Draxler, associated with the firm since 1937, is promoted from the post of assistant chief engineer.

A. W. Gruer, Jr. . . . was elected in January to the board of directors, Carondelet Foundry Co., St. Louis. He will continue his duties as manager of sales and marketing.

G. A. Gilbertson . . . president, Frank G. Hough Co., Libertyville, Ill., was elected president of the Construction Industry Manufacturers Association at the annual meeting of the group in Dallas, Texas, in January.

W. L. Kurz . . . has been elected secretary, W. W. Sly Mfg. Co., Cleveland. He will continue his present duties as assistant to the president. Kurz has been associated with the manufacturer of dust control systems, industrial ovens, blast cleaning and tumbling equipment for more than ten years.

R. M. Trent . . . is now president, and **R. H. McCauley,** director, Pangborn Corp., Hagerstown, Md. In 28 years with the company, Trent has served as Pittsburgh and West Coast district manager, and since 1957, as executive vice-president. McCauley has been the firm's general counsel for 30 years.

A. H. Jones . . . has been elected vice-president, sales and engineering, of W. W. Sly Manufacturing Co., Cleveland. He will continue to supervise product improvement and new product development programs and will direct expansion of customer service. He is a member of AFS, Northeastern Ohio Chapter.

R. E. Orr . . . has accepted appointment as sales engineer, Gregg Iron Foundry, El Monte, Calif. He was formerly with Renfrow Foundry, Los Angeles, and is a member, AFS Southern California Chapter.

George Vingas . . . formerly research director, Wehr Steel Co., Milwaukee, is now research director, Magnet Cove Barium Corp., Des Plaines, Ill. He is Chairman of the Mold Surface Committee, AFS Sand Division.

D. S. Goebel . . . has succeeded the late **J. E. Magee** as Chicago district sales manager, Wisconsin Centrifugal Foundry, Inc., and Wisconsin Stainless Foundry & Machine Corp., both of Waukesha, Wis. He was formerly with the American Smelting & Refining Co., Barber, N.J., in charge of midwest sales operations, Continuous Cast Products.

M. M. Adkison . . . has joined the staff of Alabama By-Products Corp., Birmingham, Ala., as foundry service engineer. He was with American Cast Iron Pipe Co., Birmingham, for many years as melting supervisor and later with Jackson Industries, Production Foundries Div., Birmingham, Ala.

F. J. Walls . . . has been elected vice-president, research and development, Engineering Castings, Inc., Marshall, Mich. Prior to his retirement last October, Walls was manager of the Detroit Technical Section of International Nickel Co. He has been associated with Engineering Castings since 1946 as a stockholder and director.

William Muth . . . has joined the sales force of George Sall Metals Co., Philadelphia, manufacturer of non-ferrous metal alloys, and will cover Ohio.

Lee Paddock . . . is the new foundry sales representative in northeastern Ohio for Frederic B. Stevens, Inc., Detroit, Mich. Paddock succeeds **Frank Balsley** who turned in his briefcase for a fishing rod and retired to Florida.

W. F. Wheeler, Jr. . . . former vice-president, has been elected executive vice-president and a director of American Chain & Cable Co., New York. **W. F. Wheeler, Sr.,** with more than 42 years of continuous service with the firm, has resigned as chairman of the board and chairman of the executive committee. He will continue as a director and member of the executive committee.

Wm. J. White . . . has become associated with Carver Foundry Products Co., Muscatine, Iowa. He is devoting his time to the sales and service of CO_2 equipment and supplies.

W. M. Harper . . . has been appointed sales manager in the Cleveland district office for Pangborn Corp., Hagerstown, Md.

Gordon McMillin . . . has been elected president of Canadian Steel Wheel Ltd. The firm is jointly owned by English Steel Corp., a subsidiary of Vickers (England) and Canadian Steel Foundries Ltd., a subsidiary of A. V. Roe Canada Ltd. McMillin is also president of Canadian Steel Foundries Ltd.

R. E. Lenhard . . . former executive vice-president, Air Reduction Sales Co., Inc., New York, has been appointed president of the division. He succeeds **J. H. Humberstone** who, as vice-president of the parent firm, will devote full time to corporation affairs.

J. M. Kane . . . has been promoted to director of foreign group and director of central staff by American Air Filter Co., Louisville, Ky. **J. G. Liskow** has been named sales manager in the newly-created process air division.

G. C. Rodgers has been selected as manager of the same division, brought about by merger of the dust control and engine and compressor products departments.

J. H. Bruemmer . . . has been promoted to general accountant, Hamilton Foundry & Machine Co., Hamilton, Ohio. His new duties will consist of general accounting and assisting the comptroller—**D. J. McCormick.**

F. W. Lamb . . . has been appointed general sales manager of Chicago Hardware Foundry Co., Chicago. He will supervise all the firms foundry sales divisions including welding rods, ferrous and non-ferrous castings; automatic hot-air-dryers and chairs, stools and tables; and all marketing activities.

F. R. Anderson . . . has been named chief metallurgist of Gardner Denver Co., Quincy, Ill., and will supervise metallurgical operations of all divisions.

R. D. Everett . . . has been made general superintendent of Melrose Park Works, National Malleable & Steel Castings Co., Melrose Park, Ill. Everett had been finishing department superintendent in the firm's Sharon, Pa. works.

Harry Matthieson . . . has accepted the newly-created post of vice-president of process engineering, Arwood Precision Casting Corp., New York. He was formerly plant manager of the firm's Brooklyn plant. **J. J. Shiel** has been promoted to plant manager.

C. B. Murton . . . will fill the position of sales manager, Vesuvius Crucible Co., Swissvale, Pa. Murton recently won recognition in the metal industry for his invention of a new graphite stopper head—claimed to be the first major

J. G. Kropa . . . will assume responsibility for casting sales, in addition to his present duties as manager of foundries, Chain Belt Co., Milwaukee.

Continued on page 30

advancement in stopperhead design in 30 years. **B. R. Shipley** was named assistant sales manager.

A. D. Blake . . . is the new sales engineer for Baird-Atomic, Inc., Richmond, Ill. Formerly employed as quality control engineer with General Electric Co. and Ford Motor Co., he will be responsible for sale of spectrochemical instruments.

M. D. Scraggs . . . has accepted a position with the industrial engineering department, Crane Carrier Corp., Tulsa, Okla. He is a member of AFS Tri-State Chapter.

W. G. Munro . . . is now a foundry engineer for Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago. He is a member, AFS Tennessee Chapter.

E. S. Valentine . . . has accepted a position with O. L. King & Co., Berkeley, Calif. He is a member, AFS Northern California Chapter.

Jack Cole . . . is now the iron foundry superintendent for Enterprise Foundry Co., Detroit.

F. H. Reuwer . . . is the foundry manager of Sibley Machine & Foundry Corp., South Bend, Ind. He was formerly with Lester B. Knight & Associates and is a member, AFS Chicago Chapter.

T. V. Linabury . . . has accepted a position with Miller & Company, Chicago. He is a member, AFS Chicago Chapter.

R. E. Clisby . . . retired as head of Wellington Machine Co. and Sterling Foundry Co., Wellington, Ohio. His nephew, **P. J. Clisby**, will be president-treasurer of the firm. **J. E. Glass** has been named executive vice-president; **R. G. Taylor** has been named secretary of Wellington Machine.

V. H. Patterson . . . former sales manager with Texas Foundries has taken a position as metallurgical engineer for Vanadium Corp., New York.

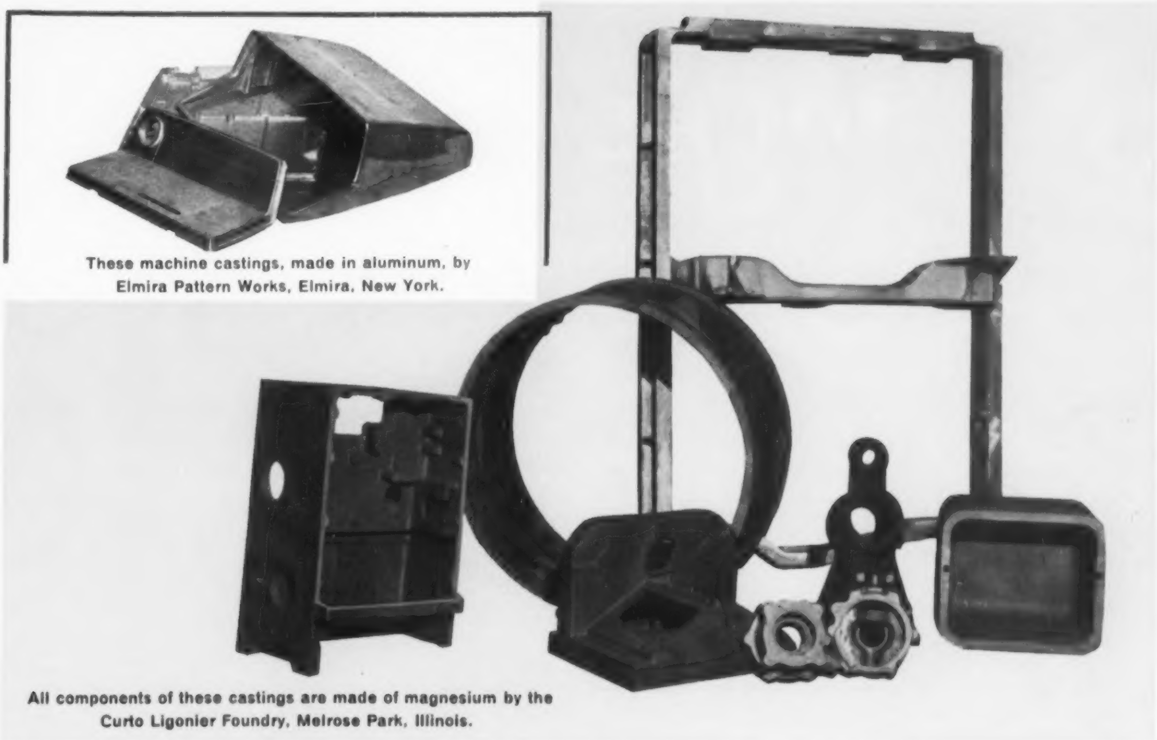
H. F. Carver . . . has been promoted to assistant general manager of Gleason Works, Rochester, New York. He will continue as vice-president in charge of sales and member of the board.

D. A. Swanson . . . has advanced from vice-president to president of Boston Electric Steel Castings Co.

H. F. Hirschel . . . has been awarded a diploma in Industrial Management by La Salle University. He is a member, AFS Philadelphia Chapter and Lehigh Valley Foundrymen's Association.

W. T. Ellison . . . has joined Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland, as sales representative in Western Illinois. He will

Continued on page 35



These machine castings, made in aluminum, by Elmira Pattern Works, Elmira, New York.

All components of these castings are made of magnesium by the Curto Ligonier Foundry, Melrose Park, Illinois.

For greater precision. . . in magnesium and aluminum castings . . . use **PETRO BOND***

Foundrymen . . . using PETRO BOND as their bonding agent . . . are obtaining greater precision in their castings.

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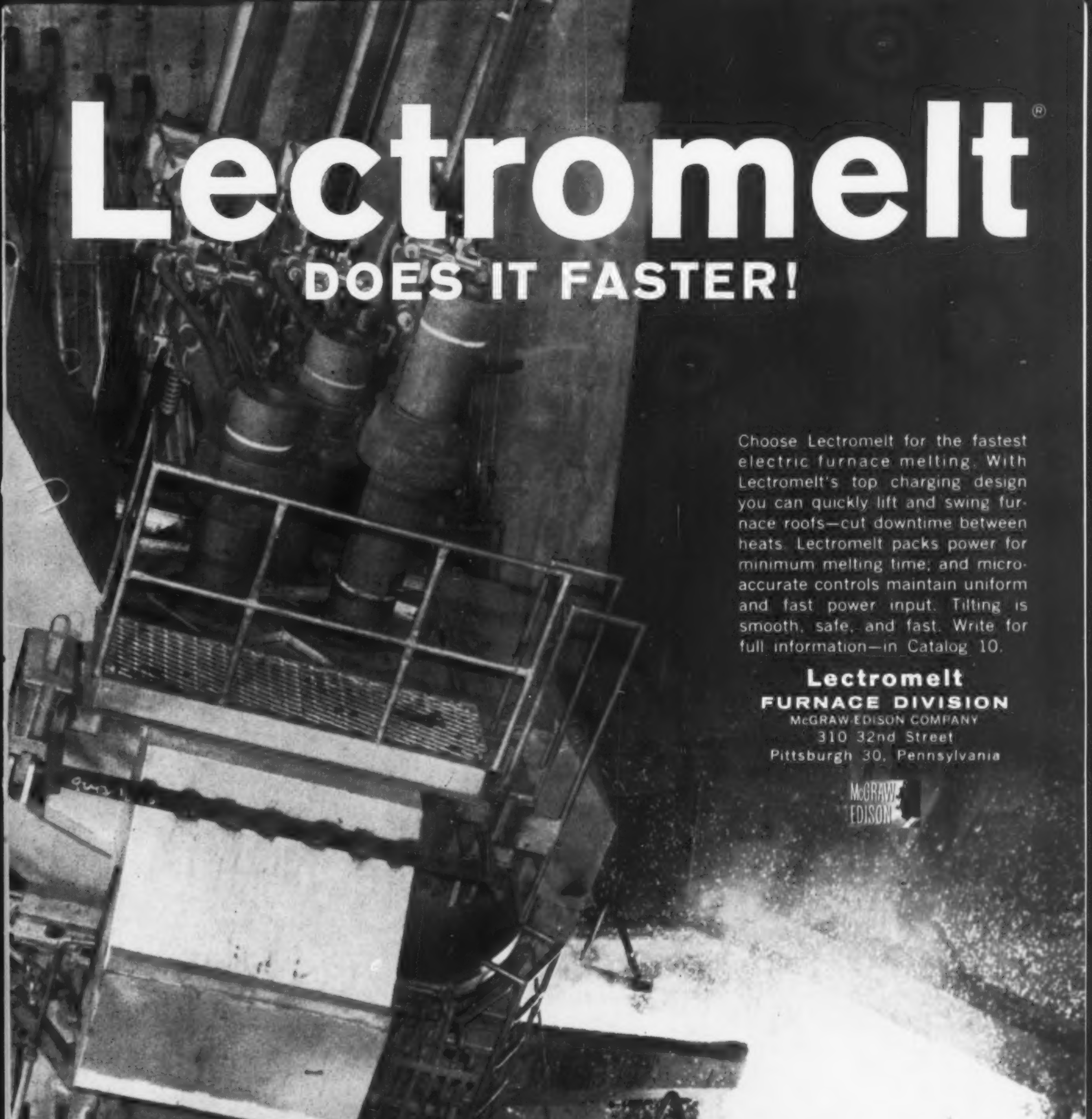
Circle No. 172, Page 167-168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let's get personal

Continued from page 30

headquarters at A-D-M's Rock Island office with **L. M. Lund.**

Wiser Brown . . . chief industrial engineer for Aluminum Co. of America, Pittsburgh, Pa., has retired after 36 years of service with Alcoa. Brown was the firm's product manager for sand and permanent mold aluminum castings and in 1949 was named to direct magnesium product sales exclusively. In 1951 he was named to the post from which he retired.

G. H. Van Schaik . . . officially assumed the duties of manager of the Chicago district office, Whiting Corp., Harvey, Ill. He succeeds **R. S. Hammond.**

obituaries

O. C. Bueg, owner, Arrow Pattern & Engineering Co., Erie, Pa., died Feb. 7. He was Chairman of the AFS Pattern Division and Assistant Membership Chairman of the AFS Northwestern Pennsylvania Chapter. He had been active for

many years both in the Society's technical activities and in chapter affairs. His widow serves as Membership Chairman of the Northwestern Pennsylvania Chapter.

Howard J. Williams, director and retired sales manager, New Jersey Silica Sand Co., Millville, N.J., died Feb. 5 at the University of Pennsylvania hospital. He had been associated with New Jersey Silica Sand Co. since 1927. Williams participated in AFS affairs and was active in establishing college foundry courses.

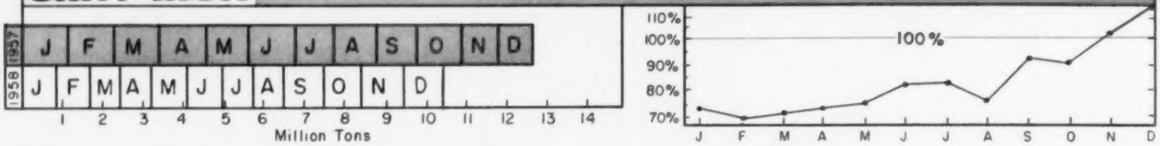
Leo Behrendt, 62, vice-president, Joseph Dixon Crucible Co., Jersey City, N.J., an expert in metallurgy, ceramics and refractories, died in Hawaii on Feb. 11. He had served as Dixon vice-president since 1948 and for seven years previously was manager of its crucible division. He was a member of AFS.

how's business . . .

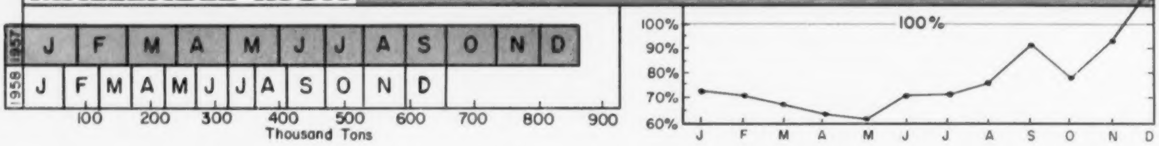
Business in the metalcasting industry is certainly picking-up. By using statistics provided by the Bureau of Census, Department of Commerce, Modern Castings has prepared this special comparison of month-to-month metalcasting shipments for the years 1957 and 1958. On the left, horizontal bar charts give a direct comparison of each month and the accumulative total for the two years.

The right-hand set of graphs demonstrate the steady upswing of business during the last half of 1958. Shipments for each month of 1958 are compared with the corresponding month in 1957 and the ratio converted to per-cent. For example gray iron shipments were 1,213,000 tons in Jan. 1957 and 868,000 tons in Jan. 1958 or about 72 per cent of the 1957 rate. So the curve starts at 72 per cent for January and climbs to 115 per cent for December when shipments of 998,000 tons exceeded 864,000 tons in Dec. 1957.

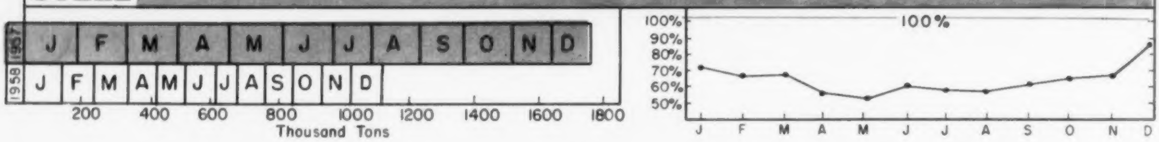
GRAY IRON



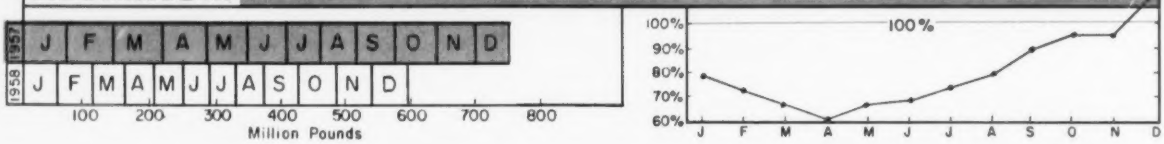
MALLEABLE IRON



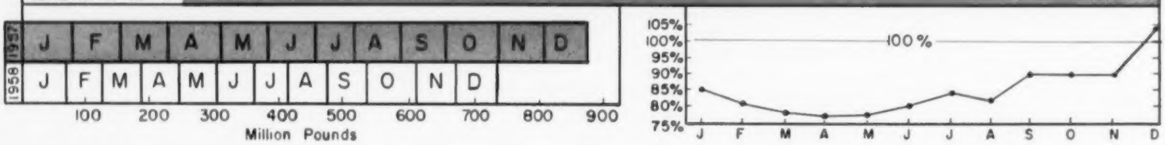
STEEL



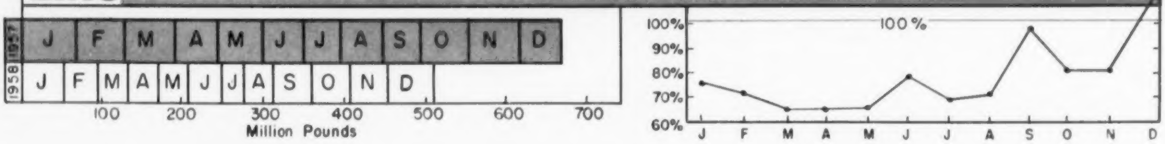
ALUMINUM



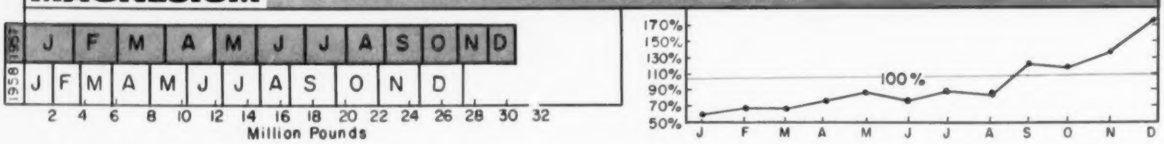
COPPER



ZINC



MAGNESIUM



Circle No. 176, Page 167-168

63d AFS CASTINGS CONGRESS AND ENGINEERED CASTINGS SHOW

The American Foundrymen's Society takes great pleasure in bringing to your attention the biggest annual event in the metalcasting industry . . . their 63rd Castings Congress and Engineered Castings Show. Five days, April 13-17, at the Sherman Hotel in Chicago, will be jam-packed with activities tuned to the interests of thousands of foundrymen, designers and casting buyers on hand for the occasion. Outstanding highlights of the week include . . . over 100 top-notch technical papers . . . an industrial exhibit of metalcastings by over 80 companies . . . national awards . . . practical shop courses . . . visits to local foundries . . . luncheons . . . banquets. MODERN CASTINGS is privileged to unveil in the following pages the complete official program and guide to this twin-bill of advanced casting technology and know-how. Use it to plan your week at the Show.

Sherman Hotel will be scene of metalcastings Show and Congress.

modern castings Feature

AFS banquets to be at Morrison.

Morris Bean & Co. will show aluminum castings.

FLOOR PLAN OF THE ENGINEERED CASTINGS SHOW

Design engineers and castings buyers throughout the nation have been invited to the 1959 Engineered Castings Show, the only exhibition planned as a demonstration of the engineering properties, adaptability and the ultimate end economy of cast metal components. Following is a listing, correct as of March 2, of the firms who will display castings, pattern equipment, alloys and test apparatus at the Sherman Hotel, April 13-17.

Adirondack Steel Casting Co., Watervliet, N. Y. Steel castings . . . **719-723**

American Brake Shoe Co., New York. Gray iron, steel, aluminum, magnesium castings . . . **1124**

American Smelting & Refining Co., New York. Non-ferrous alloy ingot . . . **707**

American Steel Foundries, Chicago. Steel and gray iron castings . . . **602**

Apex Smelting Co., Chicago. Non-ferrous alloy ingot . . . **1120**

Morris Bean & Co., Yellow Springs, Ohio. Magnesium castings . . . **833**

Bendix Foundries, Teterboro, N. J. Non-ferrous castings . . . **305**

Berlin Chapman Co., Berlin, Wis. Gray iron and aluminum castings . . . **719-723**

Brillion Iron Works, Inc., Brillion, Wis. Gray iron and aluminum castings . . . **1215**

Brush Beryllium Co., Cleveland. Beryllium and beryllium alloys . . . **407**

Buckeye Brass & Mfg. Co., Mansfied, Ohio. Ferrous and non-ferrous castings . . . **708**

Castall Precision Products Co., Chicago. Ferrous and non-ferrous castings . . . **404**

Casting Engineers, Inc., Chicago. Stainless and low alloy steel castings . . . **719-723**

Chicago Foundry Co., Chicago. Gray iron castings . . . **1228**

Consolidated Foundries & Mfg. Corp., Chicago. Gray iron, steel, and aluminum castings . . . **719-723**

Crucible Steel Casting Co., Milwaukee. Steel castings . . . **719-723**

Crucible Steel Casting Co., Cleveland. Steel castings . . . **719-723**

Curto-Ligonier Foundry Co., Melrose Park, Ill. Aluminum and magnesium castings . . . **318**

Devcon Corp., Danvers, Mass. Plastic patternmaking materials . . . **310**

Dixie Bronze Co., Birmingham, Ala. Non-ferrous castings and weldments . . . **1116**

Doehler-Jarvis Div., National Lead Co., New York. Aluminum die castings . . . **808**

Dow Chemical Co., Midland, Mich. Magnesium castings . . . **1205**

East St. Louis Castings Co., East St. Louis, Ill. Gray iron castings . . . **319**

Engineering Precision Casting Co., Inc., Matawan, N. J. Gray iron, steel, brass and bronze, aluminum castings . . . **704**

Fabricast Div., General Motors Corp., Bedford, Ind. Aluminum and alloy castings and die castings **411-415-419**

General Electric Co., Schenectady, N. Y. Gray iron, steel, brass and bronze castings . . . **1221**

Gillett & Eaton, Inc., Lake City, Minn. Gray iron and aluminum castings . . . **804**

Hampden Brass & Aluminum Co., Inc., Springeld, Mass. Aluminum and brass and bronze castings . . . **1225**

Benj. Harris & Co., Chicago Heights, Ill. Non-ferrous alloy ingot . . . **1101**

Harsch Ebaloy Foundries, Rockford, Ill. Aluminum castings . . . **719-723**

Hica, Inc., Shreveport, La. Stainless steel castings . . . **300-302**

Kaiser Aluminum & Chemical Corp., Chicago. Aluminum casting alloys . . . **715**

Keokuk Steel Casting Co., Keokuk, Iowa. Steel castings . . . **300-302**

H. Kramer & Co., Chicago. Non-ferrous alloy ingot . . . **314**

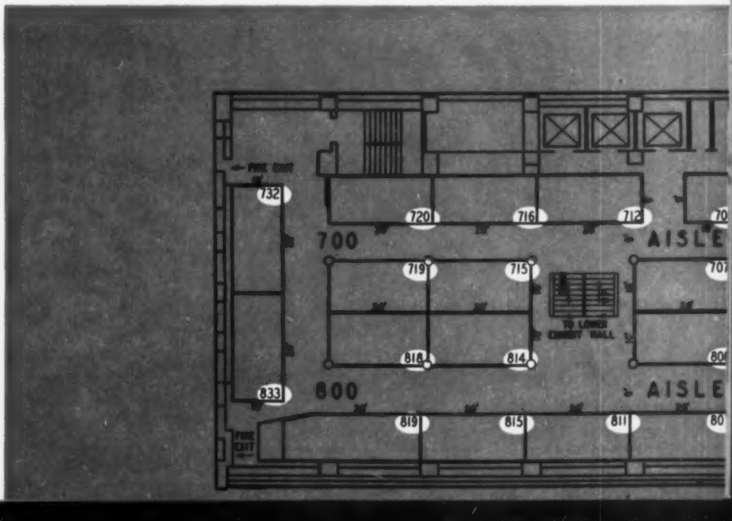
R. Lavin & Sons, Inc., Chicago. Non-ferrous alloy ingot . . . **201**

Lindgren Foundry Co., Batavia, Ill. Gray iron castings . . . **811**

Lynchburg Foundry Co., Lynchburg, Va. Gray and ductile iron castings . . . **400-402**

Magnaflux Corp., Chicago. Non-destructive testing apparatus . . . **1113**

Midwest Pressure Casting Co., Inc., Chicago. Aluminum pattern equipment and castings . . . **315**



Michiana Products Co., Michigan City, Ind. Fabricated components using castings **719-723**

Michigan-Standard Alloy Casting Co., Detroit. Steel castings **719-723**

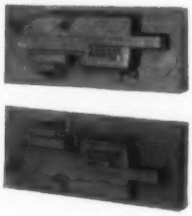
Mid-Continent Steel Casting Corp., Shreveport, La. Steel castings **300-302**

Misco Precision Casting Co., Whitehall, Mich. Steel castings .. **719-723**

Motor Castings Co., Milwaukee. Gray iron castings **1112**

Neenah Foundry Co., Neenah, Wis. Gray and ductile iron castings **1201**

American Smelting supplies alloy for cast chairs.



Shaw Process is used for cast dies.

Paxton-Mitchell Co., Omaha, Neb. Gray iron, aluminum, brass and bronze castings **309**

Pelton Steel Casting Co., Milwaukee. Steel castings **1213**

Quality Aluminum Casting Co., Waukesha, Wis. Aluminum castings . **1100**

Rausch Mfg. Co., Inc., St. Paul, Minn. Aluminum, brass and bronze castings **1202**

Roessing Bronze Co., Pittsburgh, Pa. Non-ferrous alloy ingot **1130**

Rolle Mfg. Co., Inc., Lansdale, Pa. Aluminum and magnesium castings **814**

Scientic Cast Products Corp., Cleveland. Aluminum castings **1119**

Shaw Process Development Corp., Port Washington, N. Y. Ceramic mold process **1200**

Sipi Metals Corp., Chicago. Non-ferrous alloy ingot and shot **603**

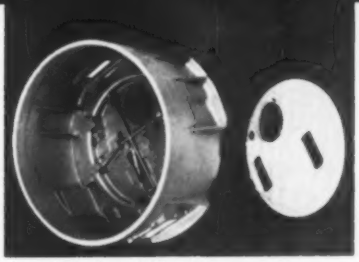
Sivyer Steel Casting Co., Milwaukee. Steel castings **732**

Southern Precision Pattern Works, Inc., Birmingham, Ala. Pattern equipment **1127**

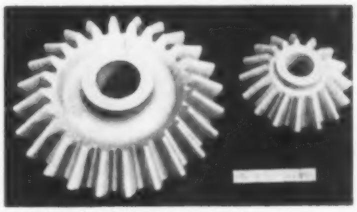
Stahl Specialty Co., Kingsville, Mo. Aluminum castings **720**

Superior Foundry, Inc., Cleveland. Gray iron castings **423**

Swedish Crucible Steel Co., Detroit. Steel castings **703**



Dow alloys for missile parts.



American Steel makes gears.

Universal Castings Corp., Chicago. Brass and bronze castings **1209**

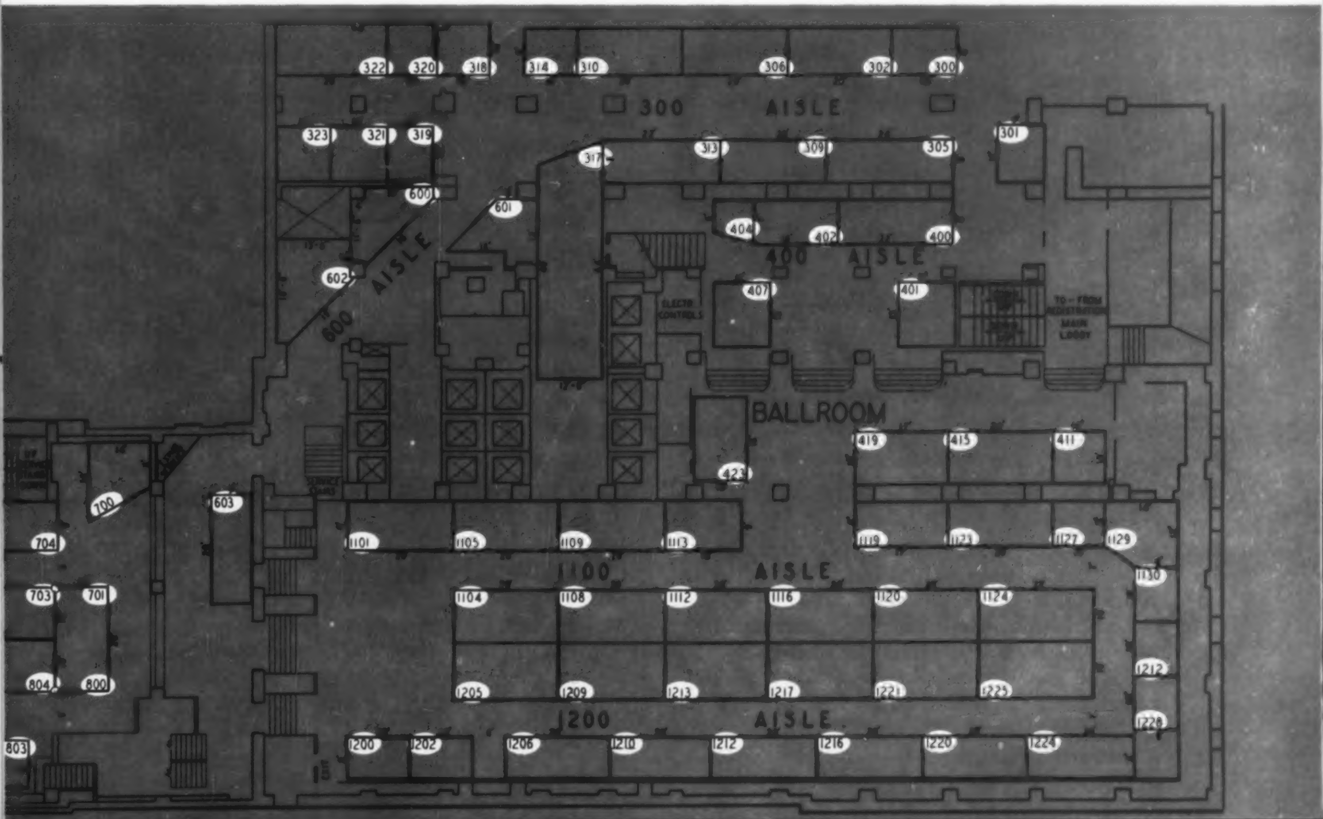
Universal Foundry Co., Oshkosh, Wis. Gray iron, aluminum, brass and bronze castings **712**

Vanadium Corp. of America, New York. Ferro alloys, metals, chemicals **313**

WaiMet Alloys Co., Detroit. Alloys, shot, ingot **719-723**

Waukesha Foundry Co., Waukesha, Wis. Stainless steel, aluminum, nickel alloy castings **1108**

Western Foundry Co., Holland, Mich. Gray iron castings **719-723**



HOYT LECTURER

HARRY M. St. JOHN

The experience of a long and outstanding career in non-ferrous metallurgy and foundry practice stands behind Harry M. St. John, the 1959 Charles Edgar Hoyt Memorial Lecturer. Mr. St. John, who will deliver a lecture on "The Control of Quality in the Brass Foundry," was awarded the Wm. H. McFadden Gold Medal by AFS in 1947 for ". . outstanding work in the field of non-ferrous casting research over a period of many years." Mr. St. John is currently active as a foundry consultant.

ANNUAL BANQUET SPEAKER

WARREN WHITNEY

A well-rounded business background combined with a sense of humor have made Warren Whitney, vice-president, James B. Clow & Sons, Inc., a successful executive and a popular speaker. He has earned the reputation of an entertaining speaker with a message.

Mr. Whitney worked as an industrial engineer, sales engineer and in public relations in the electric utilities field before entering the metalcastings industry. He started his career with Clow in 1937 and became vice-president in 1946.

Hosts to the 63d CASTINGS CONGRESS

GENERAL CONVENTION COMMITTEE

CHAIRMAN C. V. NASS
Beardsley & Piper Div.,
Pettibone Milliken Corp.

CHAPTER CHAIRMAN D. G. SCHMIDT
H. Kramer & Co.

■ AFS Chapter No. 1, the Chicago Chapter, will be the host chapter of the 63d Castings Congress. The oldest, and currently largest chapter of AFS, has formed a general convention committee and six other committees to assist in convention activities.

Members of the General Convention Committee are: Chairman C. V. Nass, Beardsley & Piper Div., Pettibone Mulliken Corp.; D. G. Schmidt, H. Kramer & Co.; W. O. McFatridge, International Harvester Co.; R. P. Schauss, Werner G. Smith, Inc.; and J. T. Moore, Wells Mfg. Co. Mr. Schmidt is the current chairman of the chapter, all other members of the general committee are past chairmen of the chapter.

A list of the other convention committees follows.

RECEPTION

CHAIRMAN J. C. GORE

■ **C. R. Lindgren,** Lindgren Foundry Co.; **R. C. Landstrom,** Miller & Co.; **M. K. Wells,** Wells Mfg. Co.; **S. C. Prest,** Griffin Wheel Co.; **L. B. Knight,** Lester B. Knight & Assoc., Inc.

PLANT VISITATION

CHAIRMAN JAMES THOMSON

■ **H. A. Young,** co-chairman, Crane Co.; **J. Semens,** U. S. Steel Corp.; **W. R. Jaeschke,** Whiting Corp.; **E. E. Ballard,** Lester B. Knight & Assoc., Inc.; **D. E. Meves,** American Steel Foundries; **L. G. Gustafson,** Blaw Knox Co.; **K. J. Jacobson,** Griffin Wheel Co.; **L. F. Bartosz,** National Malleable & Steel Castings Co.; **W. S. Duncan,** Pickands Mather & Co.; **R. J. Swain,** Woodruff & Edwards, Inc.; **R. F. Dalton; J. Geraghty,** Chicago Hardware Foundry Co.; **W. F. Tragarz,** International Harvester Co.; **P. E. Dempsey,** Kensington Steel Co.

SHOP COURSE

CHAIRMAN JOHN A. RASSENFOSS
American Steel Foundries

■ **L. H. Rudesill,** co-chairman, Griffin Wheel Co.; **A. E. Gatto,** Blaw Knox Co.; **Z. Madacey,** Beardsley & Piper Div.; **C. A. Faist,** Burnside Steel Foundry Co.; **M. Horwitz,** Chicago Malleable Castings Co.; **N. Todoroff,** Crane Co.; **C. R. Sorensen,** National Malleable & Steel Castings Co.; **T. E. Barlow,** Eastern Clay Products Dept.; **A. C. DenBreejen,** Nicol-Straight Foundry Co.; **D. R. Jones,** Illinois Clay Products Co.; **E. E. Schwantes,** International Harvester Co.; **A. Hease,** R. Lavin & Sons, Inc.; **E. W. Smith,** E. W. Smith Foundry Materials; **H. P. Stephenson,** Foundry Services, Inc.; **J. W. Lauder,** Aurora Metal Co.; **P. R. Gouwens,** Armour Research Foundation; **R. M. Frazier,** Hickman, Williams & Co.; **R. W. Schroeder,** University of Illinois; **John MacDonald,** Pettibone Mulliken Corp.; **H. C. Haines,** Woodruff & Edwards, Inc.

BANQUET

CHAIRMAN R. L. DOELMAN
Miller & Co.

■ **H. W. Johnson,** co-chairman, Wells Mfg. Co.; **R. C. Johnston,** co-chairman, Hickman, Williams & Co.; **W. L. Adams,** Eastern Clay Products Dept.; **George DiSylvestro,** American Colloid Co.; **J. M. Durrant,** U. S. Steel Corp.; **F. W. Foss,** Apex Smelting Co.; **W. M. Hofert,** International Harvester Co.; **L. J. Jacobs,** S. Obermayer Co.; **Harold Krueger,** National Bearing Div.; **R. W. McIlvaine,** National Engineering Co.; **A. A. Milkie,** Pangborn Corp.; **G. G. Morrical,** Magnet Cove Barium Corp.; **Gordon Paul,** Hansell-Elcock Co.; **W. L. Rudin,** Elesco Smelting Corp.; **R. E. Seifert,** National Malleable & Steel Castings Co.; **C. F. Semrau,** Hill & Griffith Co.; **R. W. Smith,** Dike-O-Seal, Inc.; **Gilbert Van Schaik,** Whiting Corp.

PUBLICITY

CHAIRMAN W. W. McMILLAN
International Harvester Co.

■ **H. L. Overman,** co-chairman, Whiting Corp.; **Earl Ross,** Foundry; **I. H. Dennan,** Beardsley & Piper Div.; **Dean Van Order,** Burnside Steel Foundry Co.

LADIES ENTERTAINMENT

■ **Mrs. J. C. Mulholland,** co-chairman; **Mrs. J. T. Moore,** co-chairman; **Mrs. R. W. Schroeder; Mrs. J. H. Owen; Mrs. R. M. Frazier; Mrs. L. J. Jacobs; Mrs. W. W. Moore; Mrs. W. O. McFatridge.** Pictures of committee officers appear in the Ladies Program, page 53.

Officers of the AFS

PRESIDENT

LEWIS H. DURDIN

Dixie Bronze Co.
Birmingham, Ala.

VICE-PRESIDENT

CHARLES E. NELSON

Dow Chemical Co.
Midland, Mich.

H. G. STENBERG
Vice-President
Region 1

R. W. GRISWOLD
Vice-President
Region 2

F. J. PFARR
Vice-President
Region 3

C. E. DRURY
Vice-President
Region 4

A. M. SLICHTER
Vice-President
Region 5

K. L. LANDGREBE, JR.
Vice-President
Region 6

J. R. RUSSO
Vice-President
Region 7

Terms expire 1959	Terms expire 1960	Terms expire 1961
H. W. Dietert	W. D. Dunn	D. W. Boyd
C. E. Drury	A. A. Hochrein	T. W. Curry
R. W. Griswold	K. L. Landgrebe, Jr.	R. R. Dees, Jr.
H. Heaton	F. J. Pfarr	J. Dee
J. H. King	J. R. Russo	W. L. Kammerer
A. V. Martens	A. M. Slichter	H. M. Patton
W. D. McMillan	H. G. Stenberg	C. A. Sanders
G. R. Rusk		

D. W. BOYD

T. W. CURRY

R. R. DEAS, JR.

J. DEE

H. W. DIETERT

W. D. DUNN

H. HEATON

A. A. HOCHREIN

W. L. KAMMERER

J. H. KING

A. V. MARTENS

W. D. McMILLAN

H. M. PATTON

G. R. RUSK

C. A. SANDERS

GOLD MEDAL AWARDS

Harold W. Lownie, Jr.

Mr. Lownie, Battelle Memorial Institute, Columbus, Ohio, is winner of the **John H. Whiting Gold Medal** for contributions "in the field of gray iron."

John A. Rassenfoss

Mr. Rassenfoss, American Steel Foundries, East Chicago, Ind., is winner of the **Peter L. Simpson Gold Medal** for "endeavor in steel foundry research."

Fred J. Walls

Mr. Walls, retired from International Nickel Co., Detroit, is winner of the **John A. Penton Gold Medal** for "contributions to gray iron metallurgy . ."

AWARDS OF SCIENTIFIC MERIT

Robert H. Mooney

Mr. Mooney, Central Foundry Div., General Motors Corp., is recognized for "technological contributions . . . in the malleable iron industry."

Howard H. Wilder

Mr. Wilder, Vanadium Corp. of America, Chicago, is recognized for "furthering the technology of ferrous castings and their acceptance."

Elmer C. Zirzow

Mr. Zirzow, Werner G. Smith, Inc., Cleveland, is recognized for his effort "in the development and application of sand technology."

SERVICE CITATION

James R. Allan

Mr. Allan, Allan Industries, Melbourne, Fla., is cited for service and leadership in "the improvement of foundry working conditions."

Bernard D. Claffey

Mr. Claffey, Dayton Malleable Iron Co., Dayton, Ohio, is cited for service in "the work of Chapters, Committees and educational development."

Roy W. Schroeder

Professor Schroeder, University of Illinois, is cited for service to AFS and for "his unceasing guidance of young men toward foundry careers."

OFFICIAL PROGRAM

63d CASTINGS CONGRESS AND ENGINEERED CASTINGS SHOW

REGISTRATION

Registration for both the Castings Congress and the Engineered Castings Show will be arranged at a booth on the Mezzanine of the Sherman Hotel. The registration for AFS members or non-members is $2.00.

Admittance to exhibits and technical sessions is by badge only.

MONDAY, APRIL 13

H. W. Antes

R. E. Edelman

- *8:00 am* **Author—Chairman breakfast**
  Orchid Room, Sherman Hotel

- *8:00 am* **Registration opens**

- *8:00 am* **Plant Visits**
  Approximately 20 leading foundries in the Chicago area will be open for inspection tours during the convention. Details on which plants are open for tours may be obtained daily from the Plant Visits desk.

- *9:00 am* **Ladies registration opens**

- *9:00 am* **Exhibits open**

- *9:30 am* **Light Metals**
  Bernard Shaw Room, Sherman Hotel

  Effect of Starch Content on a Rammed Graphitic Mold Material for Casting Titanium
  H. W. Antes, R. E. Edelman, Frankford Arsenal, Philadelphia

  Some Principles for Producing Sound A1-7 Magnesium Castings
  W. H. Johnson, J. G. Kura, Battelle Memorial Institute, Columbus, Ohio

- *9:30 am* **Malleable**
  Louis XVI Room, Sherman Hotel

  Malleable Iron—A Magnetic Alloy
  W. K. Bock, National Malleable & Steel Castings Co., Cleveland.

  Chemical Analysis vs Heat Treatment Effects on Tensile Strength of Malleable Iron—Controlled Annealing Committee (6D) Report
  L. R. Jenkins, Wagner Castings Co., Decatur, Ill.

  Casting Heavy Section Malleable Iron—Research Progress Report R. W. Heine, University of Wisconsin, Madison

- *9:30 am* **Pattern**
  The Assembly, Sherman Hotel

  Core Boxes for Shell Cores
  J. E. Stock, John Deere Waterloo Tractor Works, Waterloo, Iowa

  Motion Picture: "Plastic Tooling & Patternmaking with Epoxical Resins"

- *12:00 noon* **Light Metals Round Table Luncheon**
  Crystal Room, Sherman Hotel

  What Does the Test Bar Mean to the Producer and User of Castings?
  Panel: R. L. Heath, Rocketdyne Division, North American Aviation, Inc., Canoga Park, Calif., H. Rosenthal, Frankford Arsenal, Philadelphia Brooklyn, N.Y. M. E. Brooks, Dow Chemical Co., Bay City, Mich.

- *12:00 noon* **Malleable Round Table Luncheon**
  Old Chicago Room, Sherman Hotel

  Selection of Materials for Ordnance Development Programs
  V. Lindner, Feltman Research & Engineering Laboratories, Picatinny Arsenal, Dover, N.J.

  Motion Picture: "Toward More Effectice Shell"

W. H. Johnson

W. K. Bock

H. Rosenthal

D. G. Schmidt

F. L. Riddell

- *2:00 pm* **Brass and Bronze**
  Louis XVI Room, Sherman Hotel

Electrical Conductivity of Sand Cast Copper-Base Alloys
D. G. Schmidt, F. L. Riddell, H. Kramer & Co., Chicago.

Some Foundry Problems in the Development of a New Marine Propeller Alloy
A. J. Smith, Bethlehem Steel Co., Shipbuilding Div., Staten Island, N. Y.

- *2:00 pm* **Pattern**
  The Assembly, Sherman Hotel

New Horizons in Pattern Engineering Materials
J. E. Olson, Dike-O-Seal, Inc., Chicago.

Construction of and Materials for CO_2 Pattern & Core Box Equipment
R. J. Carver, Carver Foundry Products Co., Muscatine, Iowa.

- *2:00 pm* **Sand**
  Bernard Shaw Room, Sherman Hotel

Experimental Determination of Specific Surface and Grain Shape of Foundry Sands
Franz Hofmann, George Fischer, Ltd., Schaffhausen, Switzerland—presented by V. Rowell, H. W. Dietert Co., Detroit.

Critical Sodium Silicate-Sand Formulations for Optimum CO_2 Molding
R. J. Cowles, Walworth Co., Braintree, Mass.
New Foundry Resins and Application Techniques for Shell Molds and Shell Cores
W. C. Capehart, Monsanto Chemical Co., Springfield, Mass.

- *4:00 pm* **Brass and Bronze Seminar**
  Louis XVI Room, Sherman Hotel

"The Metallurgical and Foundry Aspects of Quality Control:"
Non-Destructive Testing: S. Goldspiel, New York Naval Shipyard, Brooklyn, N. Y.
Mechanical Aspects of Testing: A. J. Smith Bethlehem Steel Co., Shipbuilding Division, Staten Island, N. Y.
Fracture Testing in a Production Foundry: C. W. Ward, American Radiator & Standard Sanitary Corp., Cincinnati

- *4:00 pm* **Light Metals**
  Crystal Room, Sherman Hotel

Correlation of Radiography, Microstructure and Mechanical Properties of Magnesium—Thorium—Zirconium Alloy HK31A
T. R. Bergstrom, R. G. Bassett, Boeing Airplane Co., Seattle.

Magnesium Casting Alloy EK31XA
K. E. Nelson, The Dow Chemical Co., Midland, Mich.

- *4:00 pm* **Malleable Shop Course**
  Old Chicago Room, Sherman Hotel

Machining of Standard and Pearlitic Malleable Iron."
The Technical Aspects of Machinability Testing: L. C. Marshall, Link Belt Research Laboratory, Indianapolis
Available Machinability Data: W. C. Truckenmiller, Albion Malleable Iron Co., Albion, Mich.
Solving Machining Problems: George Kramer, Central Foundry Division, G.M.C., Saginaw, Mich.

- *5:30 pm* **Exhibits close**

- *8:00 pm* **Sand Shop Course**
  Bernard Shaw Room, Sherman Hotel

Air-set and CO_2 Binders
CO_2: C. W. Sundberg, Minneapolis Electric Steel Castings, Minneapolis; F. P. Ilenda, Diamond Alkali Co., Painesville, Ohio
Air-set: R. M. Overstrud, Reichhold Chemicals, Inc., Eastern Resin Div., Elizabeth, N.J.

F. Hofmann

T. R. Bergstrom

R. G. Bassett

TUESDAY, APRIL 14

R. A. Flinn

F. S. Sutherland

- *8:00 am* **Author—Chairman Breakfast**
  Orchid Room, Sherman Hotel

- *8:30 am* **Registration opens**

- *8:30 am* **Plant Visits**
  Approximately 20 leading foundries in the Chicago area will be open for inspection tours during the convention. Details on which plants are open for tours may be obtained daily from the Plant Visits desk.

- *9:00 am* **Ladies registration opens**

- *9:30 am* **Exhibits open**

- *9:30 am* **AFS Training and Research Institute trustees meeting**
  Holiday Room, Sherman Hotel

- *9:30 am* **Brass and Bronze**
  Louis XVI Room, Sherman Hotel

Effects of Foundry Variables upon Porosity of 85-5-5-5 Bronze—Research Progress Report
R. A. Flinn and C. R. Mielke, University of Michigan, Ann Arbor

Research in Progress in Industry:

Getting Castings Back into the Foundry: R. R. Ashley, American Radiator and Standard Sanitary Corp., Cincinnati.
Research and Development on Design of Bronze Sleeve Bearings: G. E. Langford, Superior Kendrick, Inc., Detroit.
Properties and Composition of Cast Copper-Nickel Alloys: S. Goldspiel, New York Naval Shipyard, Brooklyn, N. Y.
Research on 90-10 Cupro-Nickel Castings: E. F. Tibbetts, Wollaston Brass & Aluminum Foundry, Inc., North Quincy, Mass.

- *9:30 am* **Malleable**
  Bernard Shaw Room, Sherman Hotel

Specialized Foundry Statistical Controls Improve Customer Satisfaction
B. M. Appleman, Texas Foundries, Lufkin, Texas

Proper Gating through Use of Cobalt 60
A. J. Karam, Central Foundry Division, G.M.C. Saginaw, Mich.

Proper Interpretation and Techniques Using Magnaglo for Casting Inspection

B. M. Appleman

E. J. Gamber

H. V. Sulinski

H. Smolen

C. A. Sanders

A. R. Mead

J. C. Graddy

W. W. Moore

A. R. Lindgren, Magnaflux Corp., Chicago

▪ *9:30 am* Pattern
The Assembly, Sherman Hotel

Rigging Core Boxes for High Production Core Practice
W. H. Miller, Ford Motor Co., Cleveland Foundry Div. Berea, Ohio

Consulting Service on Pattern and Core Box Equipment Problems
Panel: M. K. Young, U. S. Gypsum Co., Chicago; R. L. Olson, Dike-O-Seal, Inc. Chicago; J. F. Roth, Cleveland Standard Pattern Works, Cleveland, R. LeMaster, R. A. Nelson Pattern Co., Milwaukee; W. E. Mason, Westinghouse Air Brake Co., Wilmerding, Pa.

▪ *9:30 am* Safety, Hygiene & Air Pollution
Gold Room, Sherman Hotel

Practical Planning for Non-Destructive Testing by Use of Radiation
F. S. Sutherland, Continental Foundry & Machine Div., Blaw-Knox Co., East Chicago, Ind.

Audiometric Testing Programs in Foundry Noise Control
H. T. Walworth, Lumbermen's Mutual Casualty Co., Chicago

▪ *12:00 noon* Brass and Bronze Round Table Luncheon
Crystal Room, Sherman Hotel

"Why Use Brass and Bronze Castings?"

The Physical and Mechanical Properties of Cast Bronze Alloys:
John Kura, Battelle Memorial Institute, Columbus Institute, Columbus, Ohio.
Where General Motors Corp. would like to use Copper Base Alloy Castings:
D. J. Henry, General Motors Corp., Detroit.
Cast Copper-Base Alloys for Corrosive Environments: C. L. Bulow, Bridgeport Brass Co., Bridgeport, Conn.

▪ *12:00 noon* Pattern Round Table Luncheon
Old Chicago Room, Sherman Hotel

Atomic Blast—A Pattern for Survival
F. B. Porzel, Armour Research Foundation, Chicago.

▪ *12:00 noon* AFS Board of Directors Luncheon and Business Meeting
Emerald Room, Sherman Hotel

Presiding: AFS President L. H. Durdin

▪ *2:00 pm* Education
Gold Room, Sherman Hotel

New Skills Required for the Shell Process
H. C. Grant, Ford Motor Co., Dearborn, Mich.

▪ *2:00 pm* Industrial Engineering & Cost
Louis XVI Room, Sherman Hotel

The Industrial Engineer—A Potential Foundry Executive
M. E. Mundel, Consultant, Milwaukee.

Practical Industrial Engineering for the Smaller Foundry
F. E. Noggle, Westover Corp., Milwaukee.

▪ *2:00 pm* Light Metals
Bernard Shaw Room, Sherman Hotel

Hot Cracking Test for Light Metal Casting Alloys
E. J. Gamber, Aluminum Co. of America, Cleveland

Sample for Rapid Measurement of Gas in Aluminum
H. V. Sulinski and S. Lipson, Frankford Arsenal, Philadelphia

Ultrasonic Attenuation in Cast Aluminum
H. Smolen, H. Rosenthal, Frankford Arsenal, Philadelphia

▪ *2:00 pm* Malleable
The Assembly, Sherman Hotel

The Effect of Bonding Clays on Pin Holes in Malleable Castings
D. R. Jones, Illinois Clay Products Co., Chicago, and R. E. Grim, University of Illinois, Urbana

Porosity—Inclusion—Pinholes in Malleable Castings
C. A. Sanders, American Colloid Co., Skokie, Ill.

▪ *4:00 pm* Gray Iron Shop Course
Louis XVI Room, Sherman Hotel

"How to Melt Several Irons in One Heat"
Panel: R. L. Johnson, Bucyrus-Erie Co., Erie, Pa.; M. D. Neptune, James B. Clow & Sons, Inc., National Works, Birmingham, Ala.; K. G. Presser, Buckeye Foundry Co., Cincinnati

▪ *4:00 pm* Malleable Shop Course
Old Chicago Room, Sherman Hotel

Symposium on Effect of Melting Variables on the Properties of Malleable Irons R. W. Heine, University of Wisconsin, Madison. Panel: W. D. McMillan, International Harvester Co., Chicago; Milton Tilley, National Malleable & Steel Castings Co., Cleveland; Eric Welander, John Deere Malleable Works, East Moline, Ill.

▪ *4:00 pm* Light Metals
Bernard Shaw Room, Sherman Hotel

How Aircraft Designers Look at Light Metal Castings
A. R. Mead, Grumman Aircraft Corp., Bethpage, N.Y.

A Preliminary Appraisal of Bending Techniques for Evaluation of Cast Metals and structures
J. C. Graddy, Douglas Aircraft Co., Santa Monica, Calif.

Design Engineering as Related to Magnesium Castings
G. H. Found, Arthur D. Little, Inc., Cambridge, Mass.

▪ *4:00 pm* Sand
The Assembly, Sherman Hotel

How to Avoid Sand Segregation
W. D. Chadwick, Manley Sand Co., Rockton, Ill.

Motion Picture: "Segregation of Sand During Handling"

▪ *4:00 pm* Steel
Crystal Room, Sherman Hotel

Interrelation Between Stress Concentration and Castability
J. B. Caine, Consultant, Cincinnati.

Aid for the Design Engineer—Accentuate the Positive
J. J. Henry, Missouri Steel Co., Joplin, Mo.

A Method of Obtaining Both Castability and Maximum Field Service from Cast Products
J. W. Beckman, Texas Foundries, Inc., Lufkin, Texas.

▪ *5:30 pm* Exhibits close

▪ *6:30 pm* Sand Dinner
Grand Ballroom, Morrison Hotel

Let's Start Over
J. B. Caine, consultant, Cincinnati

▪ *7:00 pm* Canadian Dinner

Reception, Embassy & Burgundy Rooms, Morrison Hotel
Dinner, Cotillion Room
Presiding: J. H. King, AFS National Director, Toronto

G. H. Found

H. Y. Hunsicker

J. B. Caine

J. J. Henry

D. E. Krause

H. U. McClelland

WEDNESDAY, APRIL 15

N. C. Howells

■ *8:00 am* **Author—Chairman breakfast**
Orchid Room, Sherman Hotel

■ *8:30 am* **Registration opens**

■ *8:30 am* **Plant Visits**
Approximately 20 leading foundries in the Chicago area will be open for inspection tours during the convention. Details on which plants are open for tours may be obtained daily from the Plant Visits desk.

E. A. Lange

■ *9:00 am* **Ladies registration opens**

■ *9:30 am* **AFS Annual Business Meeting**
Bal Tabarin, Sherman Hotel

Presiding—AFS President Lewis H. Durdin.
President's Annual Address
Election of Officers and Directors
Apprentice Contest Awards
Presentation of AFS Awards of Scientific Merit
Presentation of AFS Service Citations

E. Swing

■ *10:30 am* **Charles Edgar Hoyt Memorial Lecture**

The Control of Quality in the Brass Foundry.
Harry M. St. John, retired superintendent, Crane Co., Chicago

■ *11:30 am* **Exhibits open**

■ *12:00 noon* **Management luncheon**
Old Chicago Room, Sherman Hotel

"So You Want to be a President"

Developing Technical Personnel: J. H. Culling, Carondelet Foundry Co., St. Louis.
Developing Operating Supervisory Personnel :L. J. Woehlke, Grede Foundries, Inc., Milwaukee.
Developing Sales Personnel: H. A. Forsberg, Blaw-Knox Co., East Chicago, Ind.
Developing Administrative Management: F. J. Dost, Sterling Foundry Co., Wellington, Ohio.
Moderator—R. B. Parker, American Brake Shoe Co., New York

R. Kissling

■ *12:00 noon* **Die Casting and Permanent Mold Luncheon**
Bernard Shaw Room, Sherman Hotel

Vacuum Die Casting
G. R. Morton, Morton Mfg. Co., Omaha, Neb.

E. V. Blackmun

■ *2:00 pm* **Gray Iron**
The Assembly, Sherman Hotel

Continuous Carbon Injection
J. E. Wilson, R. C. Schnay, Canada Iron Foundries, Ltd., Montreal, Que.

Quantitative Measurement of the Effects of Pearlitic and Graphite on the Machinability of Cast Iron
W. W. Moore, J. O. Lord, Battelle Memorial Institute, Columbus, Ohio

Significance of Reported Chemical Analysis of Cast Iron
D. E. Krause, Gray Iron Research Institute, Columbus, Ohio

R. W. Heine

■ *2:00 pm* **Die Casting and Permanent Mold**
Louis XVI Room, Sherman Hotel

Some Practical Asepcts of Die Casting Aluminum
G. H. Found, Arthur D. Little, Inc., Cambridge, Mass., and John Lapin, Central Foundry Division, G.M.C., Saginaw, Mich.

Thermal Aspects of Cyclic Permanent Mold Operation
C. L. Goodwin, H. Y. Hunsicker, Aluminum Co. of America, Cleveland

Permanent Molding of Gray Iron
H. U. McClelland, Eaton Mfg. Co., Vassar, Mich.

E. H. King

■ *2:00 pm* **Steel**
Crystal Room, Sherman Hotel

Properties of Some Cast & Wrought Alloy Steels for Use at Elevated Temperatures
R. K. Buhr, W. A. Morgan, Dept. of Mines & Technical Surveys, Ottawa, Ont.

The Significance of Reduced Phosphorus & Sulphur Content
J. Zotos, Watertown Arsenal Rodman Laboratory, Watertown, Mass.

Foundry Characteristics of Mn-Va-Mo Age Hardening Steel
N. C. Howells and E. A. Lange, U. S. Naval Research Laboratory, Washington, D.C.

J. S. Schumacher

■ *4:00 pm* **Die Casting and Permanent Mold**
Louis XVI Room, Sherman Hotel

Evaluation of Cast Surfaces for Roughness Standards
Eldon Swing, Boeing Airplane Co., Wichita, Kan.

A Hypereutectic Aluminum-Silicon Alloy
R. Kissling, O. Tichy, Apex Smelting Co., Cleveland

X364 Aluminum Die Casting Alloy
J. H. Moorman and E. V. Blackmun, Aluminum Co. of America, Pittsburgh, Pa.

A. H. Rauch

■ *4:00 pm* **Gray Iron Shop Course**
Bernard Shaw Room, Sherman Hotel

Correction of Cupola Irregularities"
Panel—W. W. Levi, Lynchburg Foundry Co., Radford, Va.; M. H. Horton, Deere & Co., Moline, Ill.; D. E. Krause, Gray Iron Research Institute, Columbus, Ohio.

■ *4:00 pm* **Industrial Engineering and Cost**
Crystal Room, Sherman Hotel

Profit Management through Cost Control
Robert Hill, Dominion Bridge Co., Montreal, Quebec, Can.

Timestudy and Methods Training for Supervisors
John Taylor, Norris & Elliott, Inc., Columbus, Ohio.

E. M. McCullough

■ *4:00 pm* **Sand**
The Assembly, Sherman Hotel

A. deSy

Green Tensile and Shear Strength of Molding Sands
R. W. Heine, University of Wisconsin, Madison, and E. H. King, J. S. Schumacher, Hill & Griffith Co., Cincinnati

Core Stickiness Committee (8-K) Report
J. R. Young, Cadillac Motor Car Division, G.M.C., Detroit

Shell Mold & Core Committee (8-N) Report
R. J. Cowles, Walworth Co., Braintree, Mass.

■ *5:30 pm* **Exhibits close**

■ *7:00 pm* **AFS Annual Banquet**
Terrace Casino, Morrison Hotel

Presiding—AFS President Lewis H. Durdin. Presentation of AFS Gold Medal Awards Guest Speaker—Warren Whitney, James B. Clow & Sons, National Works, Birmingham

P. J. Ahearn

THURSDAY, APRIL 16

G. W. Form

J. F. Wallace

T. O. Kuivinen

S. J. Noessen

■ *8:00 am* **Author—Chairman breakfast**
Orchid Room, Sherman Hotel

■ *8:30 am* **Registration opens**

■ *8:30 am* **Plant Visits**
Approximately 20 leading foundries in the Chicago area will be open for inspection tours during the convention. Details on which plants are open for tours may be obtained daily from the Plant Visits desk.

■ *9:00 am* **Ladies registration opens**

■ *9:00 am* **Exhibits open**

■ *9:30 am* **Ductile Iron**
The Assembly, Sherman Hotel

The Tensile Properties of As Cast and Annealed Ductile Iron
A. H. Rauch, J. B. Peck, E. M. McCullough, Deere & Co., Moline, Ill.

Ductile Iron Castings vs Carbon Steel Forgings and Weldments
J. B. Salbaing, International Nickel Co., New York

■ *9:30 am* **Fundamental Papers**
Bernard Shaw Room, Sherman Hotel

Considerations of the Mechanisms of Solidificaton of Gray Iron
Albert deSy, University of Ghent, Ghent, Belgium

Grain Refinement of Solidifying Metals
R. G. Garlick, J. F. Wallace, Case Institute of Technology, Cleveland

A Rationalization of Effect of Mass on the Tensile Properties of Castings
P. J. Ahearn, Watertown Arsenal, Watertown, Mass., and G. W. Form, J. F. Wallace, Case Institute of Technology, Cleveland

■ *9:30 am* **Steel**
Louis XVI Room, Sherman Hotel

Designing for Press-Forged Castings
P. R. Gouwens, Armour Research Foundation, Chicago

Reclamation and Dimensional Accuracy of Sodium Silicate Bonded Sand
G. C. Warneke, National Malleable & Steel Castings Co., Melrose Park, Ill.

■ *12:00 noon* **AFS Past Presidents' Luncheon**
Orchid Room, Sherman Hotel

Presiding: Frank W. Shipley, Caterpillar Tractor Co., Peoria, Ill.

■ *12:00 noon* **Ductile and Gray Iron Round Table Luncheon**

What Does the Casting Designer and Buyer Expect of the Foundryman
T. O. Kuivinen, The Cooper-Bessemer Corp., Mt. Vernon, Ohio

■ *12:00 noon* **Steel Round Table Luncheon**
Old Chicago Room, Sherman Hotel

Vacuum Arc Melting
S. J. Noessen, General Electric Co., Schenectady, N. Y.

■ *2:00 pm* **Ductile Iron**
The Assembly, Sherman Hotel

Production of Ductile Iron in the Basic Direct Arc Furnace
C. R. Islieb, International Nickel Co., New York

■ *2:00 pm* **Fundamental Papers**
Louis XVI Room, Sherman Hotel

Application of Theory in Understanding Fluidity of Metals
J. E. Niesse, M. C. Flemings, and H. F. Taylor, Massachusetts Institute of Technology, Cambridge, Mass.

A Fluidity Test for Aluminum Alloys; Tripling Fluidity with a New Mold Coating
M. C. Flemings, H. F. Conrad and H. F. Taylor, Massachusetts Institute of Technology, Cambridge, Mass.

Linear Programming Applied to a Foundry Cast Problem
G. I. Gartner, Watertown Arsenal, Watertown, Mass.

H. W. Dietert

V. M. Rowell

A. L. Graham

P. W. Good

H. W. Lownie, Jr.

M. Pobereskin

W. D. McMillan

Dimensioning of Sand Casting Risers
H. D. Merchant, Case Institute of Technology, Cleveland.

■ *2:00 pm* **Heat Transfer**
Gold Room, Sherman Hotel

Design of Castings
Panel—D. J. Albanese, National Malleable & Steel Castings Co., Cleveland; A. Bain, Canada Iron Foundries, Ltd., Trois Rivieres, Que., Can.; J. L. Flitz, Central Foundry Div., G.M.C., Saginaw, Mich.; E. S. Frens, General Electric Co., Schenectady, N. Y.; R. D. Veneklasen, Niforge Corp., Boston; J. F. Wallace, Case Institute of Technology, Cleveland

■ *2:00 pm* **Sand**
Bernard Shaw Room, Sherman Hotel

Tempering of Molding Sand
H. W. Dietert, V. Rowell, A. L. Graham, Harry W. Dietert Co., Detroit

The Crust Separation Test for the Investigation of Sand Expansion Defects
P. W. Goad, The Institute of British Foundrymen, Australian Branch, Melbourne, Australia presented by L. E. Taylor, Ottawa Silica Co., Ottawa, Ill.

■ *4:00 pm* **Gray Iron**
The Assembly, Sherman Hotel

Foundries Can Produce Their Own Cast Iron Directly
H. W. Lownie, Jr., A. J. Stone, Battelle Memorial Institute, Columbus, Ohio.

Utilization of Radiosotopes in the Foundry Industry
M. Pobereskin, D. N. Sunderman, Battelle Memorial Institute, Columbus. Ohio

Report of Joint AWS—AFS Committee on Welding Iron Castings

Gray Iron: S. Low, Chapman Valve Mfg. Co. Indian Orchard, Mass.
Ductile Iron: W. W. Edens, Allis-Chalmers Mgf. Co., Milwaukee.
Malleable Iron: S. T. Walter, Air Reduction Sales Co., New York

■ *4:00 pm* **Steel**
Louis XVI Room, Sherman Hotel

Requirements for Quality Steel Castings
Y. J. Elizondo, Chance-Vought Aircraft Co., Huntington Park, Calif.

Design & Welding of Castings for Steam Turbine Applications
L. W. Songer, General Electric Co., Schenectady, N. Y.

Foundry Designing for Steel Castings
A. B. Steck, Metallurgical Associates, Inc., Melrose, Mass.

Rapid Hydrogen Determination for Steel Foundry Control
C. C. Carson and B. J. Alperin, General Electric Co., Schenectady, N. Y.

■ *5:30 pm* **Exhibits close**

■ *6:00 pm* **AFS Alumni Dinner**
Ballroom Morrison Hotel

Presiding: Harry W. Dietert, Past President AFS, Kerrville, Texas.
Basic Cupola Method of Melting
J. T. Williams, Grede Foundries, Inc., Reedsburg, Wis.

Acid Cupola Method of Melting
H. E. Henderson, Lynchburg Foundries, Lynchburg, Va.

Acid Electric Furnace Method of Melting
Louis Miller, Westinghouse Air Brake Co., Wilmerding, Pa.

D. N. Sunderman

L. W. Songer

I. C. H. Hughes

FRIDAY, APRIL 17

K. E. L. Nicholas

A. G. Fuller

■ *8:00 am* **Author—Chairman breakfast**
Orchid Room, Sherman Hotel

■ *8:30 am* **Registration opens**

■ *8:30 am* **Plant Visits**
Approximately 20 leading foundries in the Chicago area will be open for inspection tours during the convention. Details on which plants are open for tours may be obtained daily from the Plant Visits desk.

■ *9:00 am* **Exhibits open**

■ *9:30 am* **Ductile Iron**
Louis XVI Room, Sherman Hotel

Heat Treatment of Ductile Iron
W. D. McMillan, International Harvester Co., Chicago

Carbon Flotation in Ductile Iron
A. H. Rauch, J. B. Peck and G. F. Thomas, Deere & Co., Moline, Ill.

The Effect of Tin on the Structure of Flake and Ductile Irons
E. C. Ellwodd, Tin Research Institute, London, England—presented by J. A. Davis, Battelle Memorial Institute, Columbus, Ohio

■ *9:30 am* **Fundamental Papers**
Crystal Room, Sherman Hotel

Development of Low Alloy Steel Compositions for High Strength Steel Castings
H. R. Larson, F. B. Herlihy, American Brake Shoe Co., Mahwah, N. J.

A Study of Soundness & Mechanical Properties in Plates of High Steel Strength Cast Steels
H. R. Larson, H. W. Lloyd, F. B. Herlihy, American Brake Shoe Co.

High Strength Steel Castings
K. D. Holmes, J. Zotos, P. J. Ahearn, Watertown Arsenal, Watertown, Mass.

Structural Variables Influencing Mechanical Properties of High Strength Cast Steels; A Progress Report
M. C. Flemings, R. Green and H. F. Taylor, Massachusetts Institute of Technology, Cambridge, Mass.

■ *9:30 am* **Gray Iron**
Bernard Shaw Room, Sherman Hotel

Factors Influencing the Soundness of Gray Iron Castings
I. C. H. Hughes, K. E. L. Nicholas, A. G. Fuller and T. J. Szaida, Cast Iron Research Association, Molybdenum Co., Detroit.

The Effect of Mold Materials on the Cool-

T. J. Szaida

J. Hird

A. Solomon

H. L. McIntire

ing Rate and Physical Properties of Cast Metals, Report of Sub-Committee T.S. 46, The Institute of British Foundrymen, presented by John Hird, Chairman, Birmingham, England, assisted by R. W. Ruddle, Foundry Services, Inc., Columbus, Ohio

The Main Features Concerning Copper in Cast Iron
Albert deSy, University of Ghent, Ghent, Belgium

- *9:30 am* **Heat Transfer**
Old Chicago Room, Sherman Hotel

Modern Quenching Oils and Techniques for Foundry Heat Treatment
N. F. Squire, Aldridge Industrial Oils, Inc., Cleveland

Solidification Times of Simple Shaped Castings in Sand Molds
J. T. Berry, Armour Research Foundation, Chicago; G. Martin, Honolulu Oil Corp., Los Angeles; V. Kondic, University of Birmingham, England

- *9:30 am* **Sand**
The Assembly, Sherman Hotel

Timing of Expansion Scab Formation
J. E. Haller, James B. Clow & Sons, Coshocton, Ohio

Sand Movement and Compaction in Green Sand Molding
T. J. Bosworth, R. W. Heine, University of Wisconsin, Madison; J. J. Parker, SPO, Inc., Cleveland; and E. H. King, J. S. Schumacher, Hill and Griffith Co., Cincinnati

- *2:00 pm* **Gray Iron**
Louis XVI Room, Sherman Hotel

Martensitic White Irons for Abrasion Resistant Castings
T. E. Norman, Denver; D. D. V. Doane, A. Solomon, Climax Molybdenum Co., Detroit

Effect of Molybdenum on Elevated Temperature Properties of Gray Iron
G. K. Turnbull, J. F. Wallace, Case Institute of Technology, Cleveland

Ductility and Strength of High-Carbon Gray Irons
E. M. Stein, H. L. McIntire, Battelle Memorial Institute, Columbus, Ohio.

- *3:30 pm* **Exhibits close**

- *4:00 pm* **63d AFS Castings Congress and Engineered Castings Show Officially Close**

T. J. Bosworth

J. E. Haller

LADIES PROGRAM

Mrs. J. C. Mulholland

(LADIES)

- *3:00 pm* **Monday**
Walnut Room, Bismarck Hotel
Official AFS Tea

- *10:00 am* **Tuesday**
Marshall Field's Old Orchard
Shopping Tour
Buses will leave for Old Orchard from the Bismarck Hotel at 10 am

- *12:30 am* **Tuesday**
Arcade Room, Old Orchard
Luncheon and Style Show

- *10:00 am* **Wednesday**
Merchandise Mart
Conducted Tours of Merchandise Mart

- *3:00 pm* **Thursday**
Boulevard Room, Sheraton Hotel
Tea and Musicale

Mrs. J. T. Moore

MEETINGS of RELATED SOCIETIES

National Castings Council
Meeting and luncheon, Union League Club, Thursday, April 16. G. E. Seavoy presiding.

Magnesium Association
Meeting of Magnesium Association Casting Division and Fabricating Division at Congress Hotel, Thursday and Friday, April 16 and 17.

Non-Ferrous Founders' Society, Inc.
Executive Committee, Sherman Hotel, Friday, April 11
Board of Directors, Sherman Hotel, Saturday, April 12
Management Group Officers Breakfast, Sherman Hotel, Tuesday, April 14

Rapid Chemical Analysis

To facilitate and expedite chemical analysis of high nickel-chromium alloy cast irons—20 per cent and 30 per cent nickel, 2.0 per cent and 5.0 per cent chromium—our laboratory uses the filtrate from the silica separation for the manganese determination, thus saving time and expense of a seperate manganese analysis. This rapid routine method yields results accurate to the third place.

By Edward H. Huss
Viking Pump Co., Cedar Falls, Iowa

SILICON DETERMINATION: Transfer 1 gram of drillings to a 250 ml beaker; add 30 ml of 1:3 nitric acid (specific gravity 1.42) and 20 ml of 60 per cent perchloric acid. When initial action subsides, place on hot plate and heat gently until in solution. Heat more vigorously and evaporate to white fumes until the perchloric acid refluxes on the sides of the beaker for 10 minutes. Continue heating until the solution in the beaker has a syrupy appearance and consistency. Remove from heat and allow to cool approximately 120-130 F. Note carefully observe solution during refluxing and subsequent heating so it does not overheat and dry up.

■ To the cooled salts in the beaker add 100 ml of hot distilled water. Replace on hot plate and bring to boil. Immediately filter through a Whatman 41h filter paper into a 250 ml Erlenmeyer flask, washing thoroughly with hot distilled water. Wash precipitate 5 or 6 times with hot distilled water.

■ Remove the Erlenmeyer flask containing the filtrate and wash the precipitate in the filter paper with 1:10 hydrochloric acid. No hydrochloric acid should be permitted in the filtrate in the Erlenmeyer flask. Reserve the filtrate in the flask for the manganese determination.

■ After washing with dilute hydrochloride acid, again wash the precipitate with hot distilled water 4 or 5 times. Be thorough since any residual acid will cause popping and possible loss of the silica upon ignition.

■ Transfer filter paper containing the precipitate to a crucible and ignite at a minimum of 1800 F for 20 to 30 minutes. Cool in a desiccator and weigh. Calculate silicon as follows: Silicon = weight obtained x 46.72.

MANGANESE DETERMINATION: To the filtrate obtained from the silica seperation add 10 ml of a 25 per cent solution of ammonium persulfate and 30 ml of a solution consisting of 5 grams silver nitrate dissolved in 250 ml water, plus 250 ml nitric acid, plus 250 ml phosphoric acid.

■ Place the Erlenmeyer flask containing the solutions on the hot plate and bring to a boil for 10 seconds. Remove from heat and allow to cool to approximately 70-80 F. This cooling may be expedited with a cold water bath. Titrate with sodium arsenite to clear yellow end point.

■ The titrating solution is made up as follows: Add 400 ml distilled water to 100 ml sodium arsenite stock solution (stock solution—5 grams sodium arsenite to 250 ml distilled water). Standardize against a government standard sample, diluting the solution until the conversion factor from milliliters of titrating solution to per cent manganese is equal to 0.1.

1959 CASTINGS CONGRESS PAPERS

■ The technical articles appearing in this preview section of MODERN CASTINGS are the official 1959 AFS Castings Congress papers—the most authoritative technical information available to the metalcasting industry.

Nearly 100 technical papers scheduled for presentation at the 63d Castings Congress of the American Foundrymen's Society at Chicago, April 13-17, 1959, will first be officially preprinted here.

■ Readers planning to participate in oral discussion of these papers during the 63d Castings Congress are advised to bring them to the technical sessions for ready reference.

■ Written discussion of these papers is welcomed and will be included in the publication of the 1959 AFS TRANSACTIONS. Discussions should be submitted to the Technical Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

GRAY CAST IRON MACHINABILITY

quantitative measurements of pearlite and graphite effects

By W. W. Moore and J. O. Lord

ABSTRACT

Common types of unalloyed cupola-melted gray cast iron were studied to determine how changes in some of the major constituents of their microstructures affected machinability. The objective of the study was to make a contribution to the understanding of fundamental and basic factors affecting the machining ease of gray cast iron.

INTRODUCTION

The conditions for the study were set up so as to minimize or eliminate effects from three major factors known to have important adverse effects on the machinability of gray iron. These factors are:

1) The presence of the as-cast surface.
2) The presence of massive carbides.
3) The presence of iron phosphide eutectic (steadite).

The effects of these factors on machinability already have been studied in detail and are well known. Emphasis in this study was directed elsewhere—at the effects of other variables which have received less attention in prior investigations. The factors considered in this study included:

1) The relative volume of pearlite in the matrix.
2) The relative volume of graphite in the iron.
3) The relative size of the graphite flakes in the iron.

Standard A.S.T.M. bars 1.2 in. in diameter were cast in green sand at several commercial foundries from unalloyed gray irons meeting the specifications of A.S.T.M. Designation A-48, Classes 20 and 30. Some of the irons were inoculated and some were not. The matrix of the irons contained about 75 to 100 per cent pearlite, the balance being ferrite. Bars contained graphite flakes of A.S.T.M. Types A, B, D and E. The bars were free of massive cementite, and most of them were free of all but the small amounts of steadite typical of such irons.

The influence of the as-cast surface was eliminated by machining the bars to 1 in. in diameter prior to subjecting them to a constant-pressure lathe test. Bars fitting the foregoing description are, of course, generally conceded to be easily machinable.

W. W. MOORE is Principal Met., Process Met. Div., Battelle Memorial Institute, Columbus, Ohio, and J. O. LORD is Prof. of Met., Dept. of Met. Engrg., The Ohio State University, Columbus, Ohio.

S.A.E. Classification 1113 free-cutting steel (AISI B1113), was used as a basis for comparison, and was arbitrarily assigned a machinability index of 100. All gray irons in the study machined more easily than the reference steel. The irons had machinability indices of 139 to 232. The research was aimed at a determination of the causes for the machinability variation shown by these common types of gray iron.

The common practice of using reference photomicrographs to classify microstructures was not followed in this investigation. Classifications based on reference photographs are only qualitative. This study made use of lineal analysis, a quantitative method of classifying microstructure. Using this method, numerical values were obtained for:

1) The relative volume of pearlite.
2) The relative volume of graphite.
3) The relative size of the graphite flakes.

These measurements were made by metallographic examinations of specimens from each bar. Because photomicrographs were not used in this investigation, none are included in this paper.

Multiple Regression Analysis

The results of machining tests, and the results of lineal analyses of microstructures, were subjected to a multiple regression analysis of a digital computer to derive an equation relating machinability to microstructure.

The resulting equation showed that an increase in machinability rating was obtained by:

1) A decrease in the relative volume of pearlite.
2) An increase in the relative volume of graphite.
3) An increase in the relative size of the graphite flakes.

The effect of a change in size of the graphite flakes was small compared to the effects of the other two variables. Examples of the quantitative effect of these variables on machinability indices are summarized in Table 1.

Machinability ratings calculated from the new equation were compared with ratings based on tensile strength, hardness and chemical composition of the irons. Each of these three parameters is commonly used as an indication of probable machin-

ability. The method derived in this study yielded better agreement between calculated machinability index and actual machinability index than was obtained by prediction from tensile strength, hardness or chemical composition.

The findings of this study were consistent with the common understanding that machinability generally is improved in any metal by 1) reducing its strength, 2) reducing its ductility, or 3) reducing its coefficient of friction in contact with the tool. The results of this study express these effects quantitatively in terms of the major microstructural constituents in ordinary unalloyed gray iron.

SOURCE OF IRONS

Bars of 18 gray irons were produced by member foundries of the Gray Iron Research Institute. They were standard A.S.T.M. bars 1.2 in. in diameter. The mechanical properties and chemical analyses of these bars are given in Table 2.

The conditions represented in the study involved the following limitations. The bars were unalloyed, and ranged in tensile strength from about 20,000 to 40,000 psi. The bars were all of the same original diameter, and were cast in green sand molds from metal melted in commercial cupolas. Machinability tests were made after about 0.1 in. had been machined from the surface of the bars so as to eliminate effects of surface skin, surface finish and possible surface defects.

MACHINABILITY PROCEDURES

The machinability indices for this study were obtained from constant-pressure lathe tests.[1] This test was based on the fact that materials of different machining qualities cut at different rates when surface speed, depth of cut and tool geometry are held constant, and a fixed lateral force is applied to the tool. For example, the present tests on gray cast iron were conducted with:

1) Surface speed of 27 ft/min.
2) 1/8-in. depth of cut.
3) High-speed steel tool with a 12-degree side rake angle and a 0-degree back rake angle. The lateral force applied to the lathe carriage by a weight and pulley was 60 lb.

In each series of tests, several bars of cast iron, and a reference bar of B1113 steel, were treated as a group. Each individual test consisted of a number of 2-in. cuts along each bar. During each test, a record was made of the number of spindle revolutions which occurred during each of ten consecutive 0.2-in. increments of tool travel. The average of these numbers was termed the *R* value. Higher *R* values indicated smaller feeds and a bar harder to machine. To obtain a reproducible index of machinability, the *R* value of the bar under study was compared with the *R* value of the bar of reference steel used in the same series. The machinability index of the standard was taken arbitrarily as 100.

MICROSTRUCTURE EXAMINATION PROCEDURE

The microstructure of each bar was evaluated by lineal analysis.[2] Measurement was made of the amount of each phase present in the sample. A value for the relative size of graphite particle was also obtained.

The apparatus used in lineal analysis was a Hurlbut counter, a device for measuring the travel of a mechanical stage under a microscope. The mechanical stage was driven by a motor through a gear train. The stage could be moved by engaging any one of seven similar gear trains. Each gear train was provided with a numerical counter to record the

TABLE 1 — MICROSTRUCTURE CHANGES EFFECTS ON GRAY CAST IRON MACHINABILITY

	Machinability Index in the Constant-Pressure Lathe Test (1113 Steel = 100, Higher Indices Indicate Better Machinability)	
Condition[1]	Index	Change in Index Due to Indicated Change in Microstructure
Average for irons studied (93.8% pearlite, 8.29% graphite, relative size of graphite — 3.32 microns)	179	0
Decrease of 10 per cent in volume of pearlite only. For example, from 93.8% to 84.4%	191	+12
Increase of 10 per cent in volume of graphite only. For example, from 8.29% to 9.12%	189	+10
Increase of 10 per cent in relative size of graphite only. For example, from 3.32 to 3.65 microns	179.4	+0.4
Cumulative effect of a decrease of 10 per cent in volume of pearlite, increase of 10 per cent in volume of graphite, and increase of 10 per cent in relative size of graphite	201.4	+22.4

1. Percentages refer to relative volumes.

TABLE 2 — TEST BARS PROPERTIES AND COMPOSITIONS[1]

Bar No.	Tensile Str., psi	Bhn	Chemical Composition, % TC	Si	C.E.[2]	Mn	S	P
W - 1	38,000	207	3.26	2.06	3.95	0.92	0.09	0.11
W - 2	38,100	207	3.24	2.27	4.00	0.92	0.09	0.11
W - 3	27,900	183	3.35	2.42	4.16	0.66	0.15	0.09
W - 4	27,600	179	3.37	2.65	4.25	0.66	0.15	0.09
W - 5	32,200	197	3.24	2.35	4.02	0.51	0.13	0.18
W - 6	34,200	192	3.20	2.53	4.04	0.51	0.13	0.18
W - 7	31,900	187	3.37	2.01	4.04	0.71	0.10	0.10
W - 8	27,700	174	3.39	2.41	4.22	0.71	0.10	0.10
W - 9	30,900	208	3.48	1.70	4.05	0.38	0.06	0.49
W - 10	29,600	199	3.48	1.90	4.11	0.38	0.06	0.49
W - 11	20,900	170	3.63	2.58	4.49	0.57	0.11	0.17
W - 12	19,500	174	3.63	2.67	4.52	0.57	0.11	0.17
W - 13	22,100	172	3.63	2.58	4.49	0.57	0.11	0.17
W - 14	22,200	174	3.63	2.67	4.52	0.57	0.11	0.17
W - 15	31,900	192	3.38	2.29	4.14	0.90	0.11	0.08
W - 16	32,400	197	3.38	2.42	4.19	0.90	0.11	0.08
W - 17	38,900	207	3.26	1.78	3.85	—	—	0.30
W - 18	39,200	207	3.22	1.91	3.86	—	—	0.30

1. Information in this table furnished by Gray Iron Research Institute.

2. $C.E. = T.C. + \frac{1}{3} Si.$

travel of the stage while that gear was engaged. The microstructure of the specimen being examined was viewed through a metallurgical microscope at a magnification of 1000 ×.

A cross-hair in the eye piece provided a reference point. A series of traverses was made of each specimen. Each microconstituent under study was assigned to one gear train. The stage was moved by engaging only the gear train assigned to the particular microconstituent under the reference hair at any given instant.

Tabulated results of the measurements and calculations for:

1) Relative volume of pearlite;
2) relative volume of graphite;
3) relative size of graphite flakes;

are given in Table 3 for each of the 18 irons included in the study. Table 3 also includes the machinability indices determined experimentally on each iron.

The total distance of travel of the reference point across the specimen during any one traverse was taken as L. The sum of individual distances traveled across one particular phase during the same traverse was taken as L'. The ratio of L'/L was taken as V', the relative volume of the particular phase as a fraction of the total volume of all phases.

Graphite Size Determination

The average relative size of graphite flakes was determined with the use of the Hurlbut counter in the following manner. In a given traverse, measurements were made of:

1) The sum of the individual distances in microns* that the reference point traveled across graphite flakes.
2) The number of graphite flakes.

The division of the sum of the distances in microns by the number of flakes yielded a value which was taken as the average relative size of the graphite flakes in microns. The resulting numerical value for relative size of flakes was not a measure of any specific dimension of the flakes.

In the Hurlbut-counter method, accuracy of measurement is inversely proportional to the size and the number of the areas of the particular phase undergoing measurement. When a traverse involves measurements on a large number of particles of small size (as in the measurement of the volume of graphite flakes in gray iron), the accuracy of the Hurlbut-counter method is lower than when a fewer number of larger particles or phases is measured. To double check on the counter method, separate and independent calculations were made to estimate the relative volume of free graphite in each bar.

The relative volume of pearlite in the microstructure was measured. The total carbon content of the irons was determined by analysis. The pearlite in each bar was assumed to contain 0.8 per cent of carbon. Because the irons contained no massive carbides, the balance of the total weight of carbon in the iron was assumed to exist as free graphite.

*1 micron = 0.001 mm = 0.00004 in.

TABLE 3 — MACHINABILITY TESTS AND MICROSTRUCTURE ANALYSES DATA

Bar No.	Machinability Index[1]	Relative Volume of Pearlite (V_p), %	Relative Volume of Graphite (V_g), %[2]	Relative Size of Graphite (S_g), microns[3]
W - 1	151	99.8	7.78	2.67
W - 2	153	100.0	7.59	3.46
W - 3	184	99.5	7.96	3.85
W - 4	185	97.2	8.08	3.65
W - 5	198	76.6	8.18	3.12
W - 6	179	92.7	7.73	3.16
W - 7	177	98.1	8.06	3.24
W - 8	177	99.6	8.08	3.77
W - 9	177	99.9	8.54	5.01
W - 10	169	99.6	8.52	4.00
W - 11	203	89.7	9.09	2.61
W - 12	203	85.2	9.21	2.12
W - 13	193	83.0	9.26	2.18
W - 14	232	72.8	9.65	2.15
W - 15	164	97.8	8.09	1.39
W - 16	165	99.7	8.09	3.55
W - 17	164	97.3	7.76	4.93
W - 18	145	99.2	7.63	4.90

1. Basis is machinability index of B1113 steel = 100.
   Higher indices indicate better machinability.
   Tabulated values are averages of six 2-in. cuts on each bar.
2. Based on calculation from relative volume of pearlite and total carbon content as described in the text.
3. 1 micron = 0.001 mm = 0.00004 in.

By use of the relative densities of graphite and iron, the calculated weight of free graphite in the iron was converted to relative volume of graphite in the iron. These calculated values were uniformly about 20 per cent lower than the values obtained by the counter method. Because of this uniform relationship between the two methods, it was possible to use the results of either method for defining the relative volume of graphite in different samples.

VARIABLES EFFECTS ON MACHINABILITY INDEX

The machinability indices of the irons were found to be related to each of the three variables studied. Figure 1 shows how the machinability index decreased when the amount of pearlite in the matrix

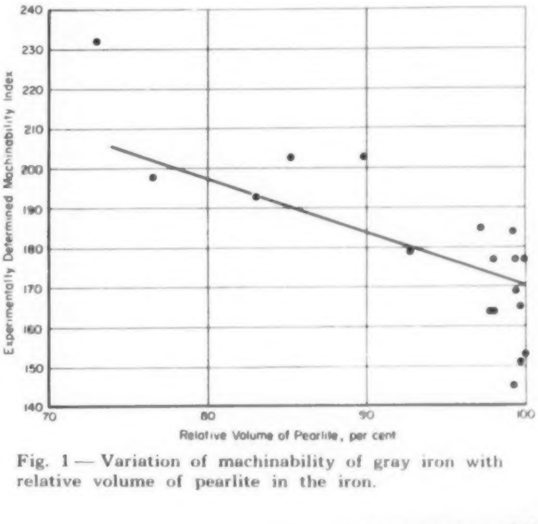


Fig. 1 — Variation of machinability of gray iron with relative volume of pearlite in the iron.

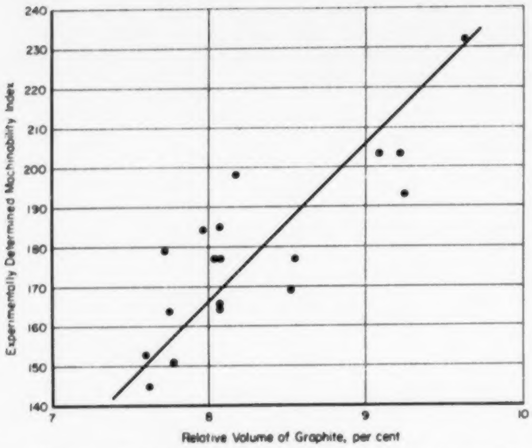


Fig. 2 — Variation of machinability of gray iron with relative volume of graphite in the iron.

increased. The spread of data points above about 97 per cent of pearlite is easily explainable. The iron cannot contain more than 100 per cent of pearlite. Once an iron contains about 100 per cent of pearlite, factors which affect machinability adversely obviously cannot be accompanied by a proportional increase in the percentage of pearlite. This explains the results on the three irons which had low machinability indices of about 140 to 160, and which also had virtually a completely pearlitic matrix.

Figure 2 shows how machinability increased with an increase in the relative volume of graphite in the iron. Figure 3 shows that an increase in the average relative size of the graphite flakes tended to cause a decrease in machinability, but that the relationship between machinability index and the size of the graphite flakes was more variable than the relationship shown in Figs. 1 and 2.

Figures 1 through 3 show that each of the three variables under study have approximately a linear effect on machinability index over the range of

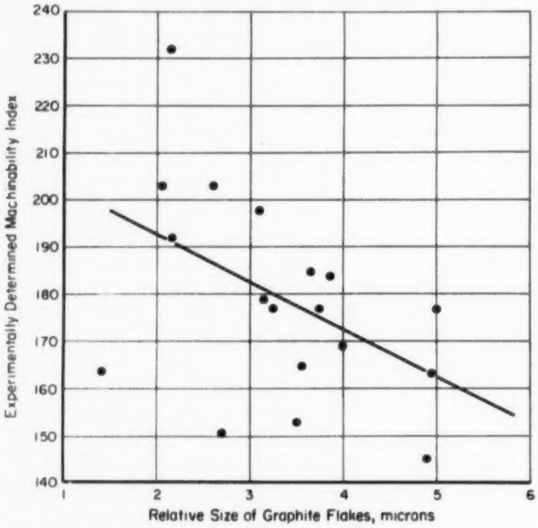


Fig. 3 — Variation of machinability of gray iron with relative size of graphite flakes in the iron.

variables studied. Because each variable had an effect, it is to be expected that graphs of machinability index against only one of the three variables would show considerable scatter. It was decided, therefore, to combine the effects of the three variables into one parameter.

Assuming that a linear relationship existed for each variable, a multiple regression analysis was performed on an I.B.M. digital computer to derive an equation which combines the effects of all three variables on the machinability index. The resulting equation which best fits the experimental data was as follows:

$$M = 195.5 - 1.26\, V_p + 11.7\, V_g + 1.2\, S_g$$

where

M = Machinability index.
V_p = Relative volume of pearlite in per cent.
V_g = Relative volume of graphite in per cent.
S_g = Relative size of graphite in microns.

Figure 4 shows how the machinability indices calculated from this equation compared with the indices which were determined experimentally.

NEW METHOD EVALUATION

Three bases sometimes used to predict the machinability of gray iron are:

1) Chemical composition as defined by the carbon equivalent (C.E. = T.C. + $\frac{1}{3}$ Si) of the iron.
2) Brinell hardness of the iron.
3) Tensile strength of the iron.

Figures 5, 6 and 7 show the relationship between each of these three parameters and the machinability indices determined experimentally.

A comparison was made of the accuracy with which each of these three parameters and the new method would predict machinability. The results of

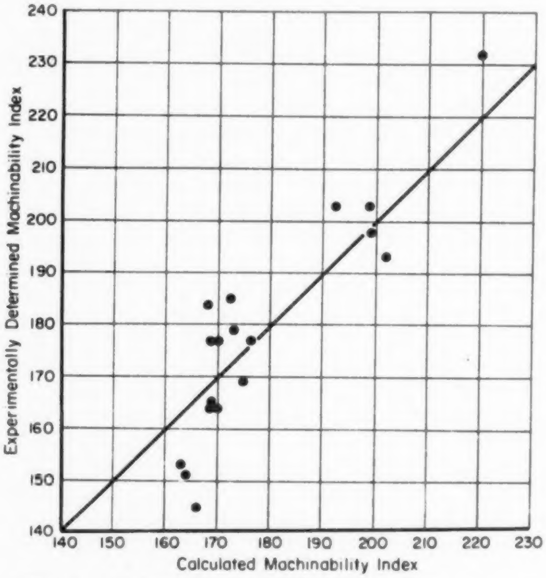


Fig. 4 — Comparison of machinability indices calculated from the multiple regression equation with machinability indices determined experimentally.

this comparison are shown in Fig. 8. The new method based on microstructure gave the best correlation between predicted and actual values for machinability. Prediction based on carbon equivalent was second.

A particular value of the new method based on microstructure is that its use would call attention to the presence of factors other than those included in this study. Specifically, examination of the microstructure will reveal the presence of massive carbides and steadite which are extremely harmful to machinability. None of the other methods can be depended upon to do this.

INOCULATION EFFECT

Because some of irons included in the study had been inoculated and some had not, a determination was made of how inoculation affected ability to predict machinability from examination of the microstructure. Figure 9 is the same as Fig. 4, except that Fig. 9 indicates which irons had been inoculated and which had not.

Figure 9 shows that the relationship between calculated and actual values for the machinability indices was not affected by inoculation. This does not imply that inoculation had no effect on machinability. Figure 9 shows that any effect which inoculation did have on machinability was detected and evaluated by the method used. The method, therefore, is equally applicable to inoculated and to uninoculated irons machined under the same conditions as those used in this study. In this connection, it is necessary to recall that the surface layer of the bars is most affected by inoculation, and that the surface layers of all bars were removed prior to testing.

PHOSPHORUS CONTENT EFFECT

Phosphorus in gray iron is generally considered to have a deleterious effect on machinability because

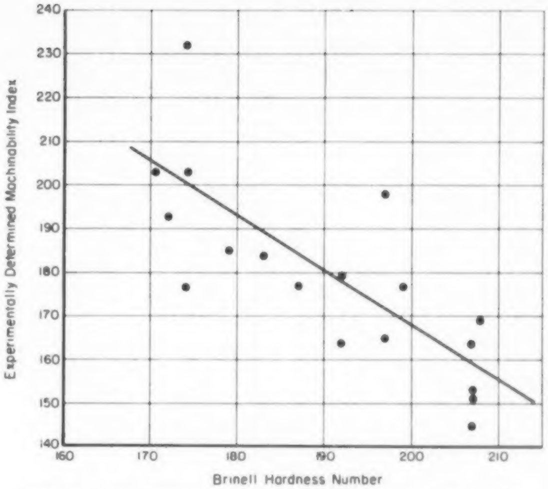


Fig. 6 — Relationship of machinability to Brinell hardness number.

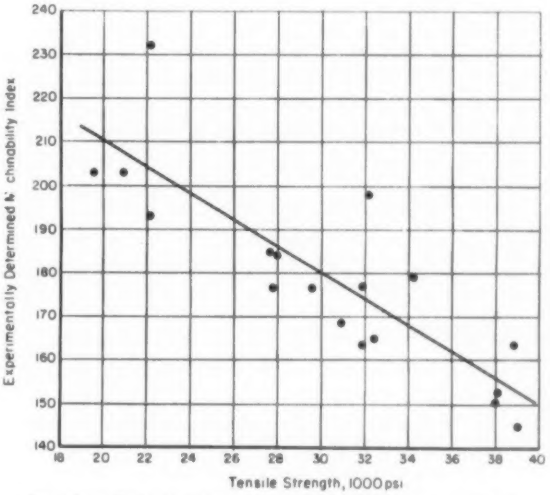


Fig. 7 — Relationship of machinability to tensile strength.

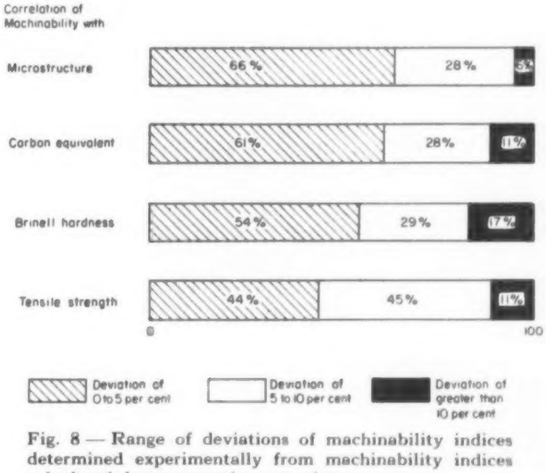


Fig. 8 — Range of deviations of machinability indices determined experimentally from machinability indices calculated from regression equations.

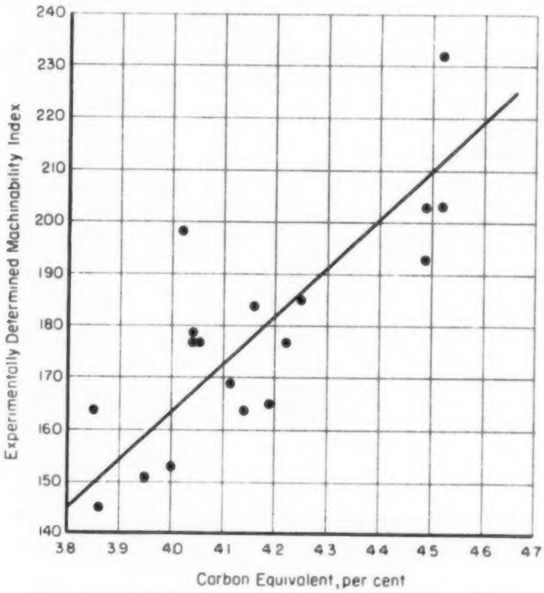


Fig. 5 — Relationship of machinability to carbon equivalent.

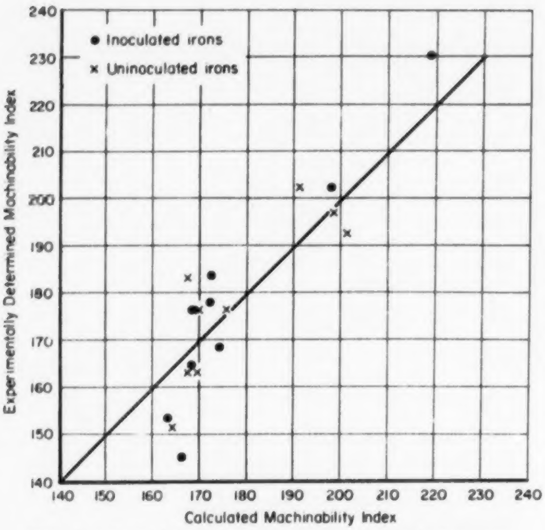


Fig. 9 — Inoculation effect on the relationship between machinability indices determined experimentally and machinability indices calculated from microstructure.

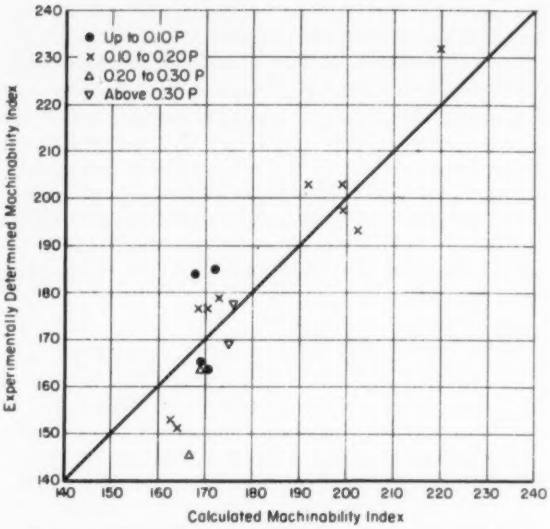


Fig. 10 — Phosphorus content effect on the relationship between machinability indices determined experimentally and machinability indices calculated from microstructure.

phosphorus occurs in the microstructure mainly as hard massive steadite (iron phosphide eutectic). Table 2 shows that the irons in this study contained 0.08 to 0.49 per cent of phosphorus.

Figure 10 is the same as Figure 4, except that the phosphorus content of each iron is indicated. It shows that the relationship between calculated and actual vaues for the machinability indices was not affected significantly by phosphorus contents between 0.08 and 0.49 per cent.

DISCUSSION

The determined effects of pearlite and graphite on the machinability of gray iron were consistent with general principles of machinability. Generally, factors which reduce the strength and/or ductility of a metal increase its machinability. A decrease in the amount of pearlite, or an increase in the amount of graphite, will decrease both the strength and the ductility of gray iron, and each of these effects was found experimentally to increase machinability.

The effect of the size of the graphite flakes is particularly interesting. When a simple correlation is made between machinability and the size of graphite flakes (as in Fig. 3), the effect of the size of the flakes is masked by the effects of changes in the amount of pearlite and the amount of graphite. The multiple regression analysis shows that there is a true effect of the graphite flakes size upon machinability.

Measurement of the relative sizes of the graphite flakes may be useful for another purpose. Coarse (large) flakes may indicate general coarseness of microstructure. This is suggested by Field and Stansbury[3] who show that machinability is improved by coarser microconstituents. This possibility is of particular interest since the coarsening of microstructure studied by Field and Stansbury was brought about by changes in section thickness.

Boulger[4] indicates that machinability may be directly affected by graphite size with larger particles being more effective in decreasing friction. This situation would be analogous to the improvement in machinability brought about by increased size of sulfide particles in a free-machining steel.

ACKNOWLEDGMENT

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MALLEABLE IRON A MAGNETIC ALLOY

By W. K. Bock

ABSTRACT

Malleable iron is well-known for its strength, toughness and machinability, and is frequently specified where these properties are of prime importance. Malleable iron also has excellent magnetic properties, and although it has been specified for electromagnetic applications designers have not had, in one place, data available to them on the magnetic properties. This paper is presented to correct that situation.

INTRODUCTION

The work considered here will be divided under three general headings:

1) Magnetic theory with definitions and calculations.
2) Magnetic properties.
3) Other properties.

The first section will not be necessary to the designers who work regularly with magnetic problems. However, it is offered, without apology, because some designers may find it handy, and because it gives a background for the argument that malleable iron is worthy of serious consideration as a magnetic material.

The second section, dealing with magnetic properties, will give the important properties of malleable iron and, in order that the reader may have a chance of comparison, will also give properties of other soft magnetic alloys.

The magnetic properties of materials which could be considered for electromagnetic applications are so nearly alike that the final choice is often decided on other properties such as ease of forming, machinability, strength, etc. Therefore, in a review dealing with the use of malleable iron as a magnetic material, it is natural to compare pertinent nonmagnetic properties of malleable and other materials.

MAGNETIC THEORY

Magnetism is a natural force which can be made to perform many useful functions. The two elements in every application are a magnetic field and a magnetic material, that is, a material which can respond to a magnetic influence.

The earliest application of the phenomenon was the use of lodestone for direction finding. Magnetite, the mineral of which lodestone is composed, is a natural permanent magnet, and its unique property is still used in the beneficiation of iron ore. Today, however, in an engineering sense, magnetite or lodestone is not considered a magnetic material.

Present day magnetic alloys are based on three ferromagnetic metals. Ferromagnetic elements are those which have strong susceptibility to magnetic fields. Of the 92 naturally occurring elements, only four are ferromagnetic: iron, cobalt, nickel and gadolinium. Since the last is a scarce rare earth metal, it is of no commercial importance.

Any one of these metals will lose its magnetic quality if heated to a sufficiently high temperature. Gadolinium is ferromagnetic only at low temperatures. Each of the others has a well-defined temperature, called the Curie point, above which they lose their ferromagnetism. These Curie points are given in Table 1.

TABLE 1 — CURIE POINTS OF ELEMENTS

Metal	Curie Point °C	Curie Point °F
Iron	768	1414
Cobalt	1115	2039
Nickel	353	665

In order to react to a magnetic influence, the metal must become a magnet. The mechanism involved has been the subject of much theorizing. At one time, the accepted theory was that each atom was a subminiature magnet, and these magnets were normally oriented randomly and their effects cancelled out. When a magnetic field was applied, these atomic magnets lined up, and their effect was additive and the metal made a magnet.

Domain Magnetic Theory

This theory has largely been superseded by the domain theory, which states that blocks of atoms act together to produce a magnetic effect. The details of the mechanism belong to the field of atomic physics, and are beyond the scope of this paper. There must be some justification of the viewpoint, however, because out of the domain theory came the Heussler alloys which are ferromagnetic, but composed of the nonmagnetic metals aluminum, copper and manganese.

In the space around a magnet, the influence of a magnet can be detected. The simplest demonstration of this is the high school physics experiment in which a sheet of paper is placed over a bar magnet and is sprinkled with iron powder. With little coaxing the iron filings line up to form a pattern, like that in

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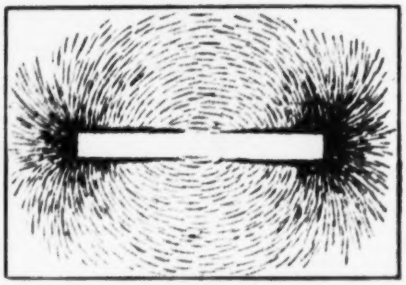

Fig. 1 — Cross-section of magnetic pattern using a bar magnet.

Fig. 1. Of course, the pattern mapped out by the iron is only a cross-section of the whole field.

Demonstrations like this make it easier to introduce the concept of a line of force. The magnetic field can be considered to be made up of a bundle of lines of force, each one running from the North Pole to the South Pole. The lines of iron particles in Fig. 1 show this. Of course, this picture of the magnetic field is not a true one, because the magnetic field is a continuum, but the effect of the field is much like that of a number of lines.

Field Intensity

In order to describe the strength of a magnetic field at any point in space, it is natural to state the number of lines per unit area measured in a plane at right angles to the direction of the lines of force. Such a definition of field strength or field intensity is not practical for magnetic work, and so the unit of field intensity which is commonly used is the "oersted."

A rigorous definition of the oersted would sound too metaphysical for this paper, so it is "defined" here in terms of a common method of producing a magnetic field. A magnetic field can be generated by passing an electric current through a coil of wire or a solenoid. The field intensity (number of oersteds) depends on the number of turns of wire in the coil per inch of its length, and on the number of amperes of current flowing. The number of oersteds can be found by the following expression.

$$\text{Oersteds} = 1.2566 \text{ ampere-turns/cm} = 0.4947 \text{ ampere-turns/in.} \qquad (1)$$

If a piece of iron, or other ferromagnetic substance, is placed in the coil, the lines of force will prefer to go through the iron rather than the air. Thus, the iron core will tend to concentrate the magnetic field of the solenoid. A certain flux density will be induced in the iron. By proper laboratory techniques, it is possible to determine how many lines per unit area of iron are induced.

The unit for reporting the result is the gauss, which is defined by:

$$\text{Gauss} = 1 \text{ line/sq cm} = 0.155 \text{ line/sq in.} \qquad (2)$$

There may be some question why both the oersted and the gauss are necessary, since both are lines per unit area. The answer lies in the fact that the above "definitions" were not rigorous. They are correct, but not complete.

In any magnetic design a magnetic field of given strength is supplied, generally by means of electric current in a solenoid. A ferromagnetic part, the core (usually of iron), is placed in the magnetic field. The induced magnetism is then used to produce a pulling or turning or other action for which the part was designed. How much useful force will be exerted will depend on how many gausses of magnetic flux will be developed by the number of oersteds of field strength available. It follows that, for design purposes, one piece of information needed is the relationship of induced magnetism to the magnetizing force of the solenoid.

The B-H Curve

In magnetic calculations the magnetizing force is denoted by the letter H, and the induced field by B, so the curve is referred to as the B - H curve. The shape of the B - H curve is shown in Fig. 2.

The shape of the curve is explained by the operation of the domain theory. At low magnetizing forces there are plenty of atoms to form domains, and so a little change in magnetizing force induces a certain change in the induced magnetism. At higher magnetizing forces a greater portion of the atoms are already in domains, and the same change in magnetizing force produces less change in the induced magnetism. Finally, the domain structure is complete and further magnetizing force produces no further strength. The value of the induced magnetism at this point is called the saturation value. This value stated in gausses or kilogausses (1000 gauss) is a characteristic of each alloy.

Another important magnetic property is the permeability, which is a measure of the ease with which magnetic lines of force can pass through the metal. This quantity is usually denoted by μ. By definition:

$$\text{Permeability} = \mu = \frac{B}{H} = \frac{\text{Induced magnetic flux}}{\text{Magnetizing field}} \qquad (3)$$

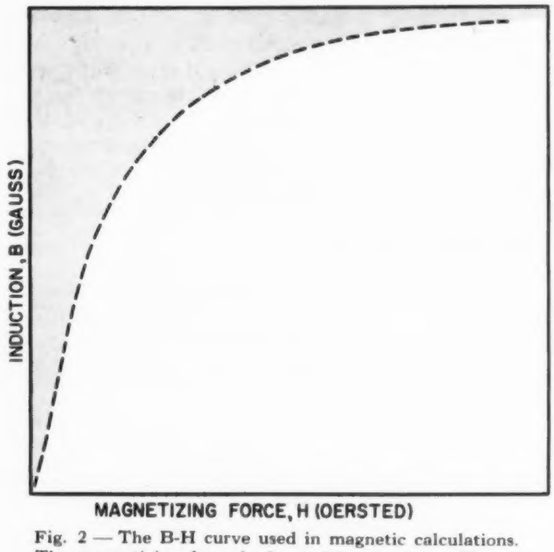

Fig. 2 — The B-H curve used in magnetic calculations. The magnetizing force is denoted by the letter H, and the induced field by the letter B.

So far, the discussion has dealt with the behavior of a magnetic system when a magnetizing force is applied. In any practical use of magnetism the field is applied for a while and then cut off or reversed. For descriptive purposes it is easiest to consider the case where magnetic field is built up in one direction, slowly reduced to zero, built up in the opposite direction, returned to zero and then re-cycled. The entire sequence of events is shown by Fig. 3.

As the magnetizing force is increased to some value H^* oersteds, the induced magnetism will follow a curve, like that of Fig. 2, but when the magnetizing force is decreased the induced strength will not retrace the original curve, but will lag behind so that when H, the magnetizing force, reaches zero there will still be some magnetism in the magnetic material. This is shown by the point B_0. The extent of this retentivity, or retained magnetism, depends on the magnetic material and on the maximum value of the magnetizing force (H^*) which has been used.

Having reached zero the field force can be built up in the opposite direction. The induced magnetic strength will decrease until the magnetizing force reaches a value $-H_0$, where the induced magnetism is reduced to zero. The absolute value of the magnetizing force at this point is the coersive force, which depends again on the metal and on the maximum inducing force used.

As the inducing force goes on to $-H^*$ and back through zero to $+H^*$, the rest of Fig. 3 is traced out.

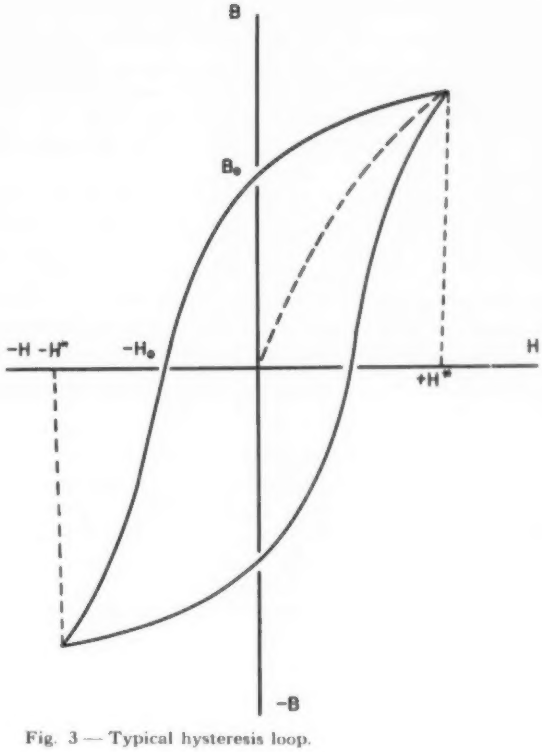

Fig. 3 — Typical hysteresis loop.

Hysteresis Loss

The shape of the loop in Fig. 3 or, more important, its area, depends on the metal and the maximum magnetizing force. Since this area of the loop is so important for efficient operation of some magnetic designs, the hysteresis loss is an important design factor. This is the power lost in the metal, and is proportional to the area of the loop.

Hysteresis loss is usually denoted by the letter h, and the units used are ergs/ccm/cycle. There has been an attempt to relate the hysteresis loss h to the maximum value B of induction in the cycle. For this, it is necessary to use the Steinmetz constant η. The relationship is

$$h = \eta B^n \tag{4}$$

where the exponent n is about 1.6 for iron and iron-silicon alloys for limited range of magnetization. It is much greater for cast iron. The Steinmetz constant depends on the metal or alloy and runs from 0.0007 for iron-silicon alloy to 0.025 for some steel. Clearly, lower values of the Steinmetz constant are desirable to minimize the hysteresis loss.

Due to limitations of conditions under which the above equation applies the utility of the Steinmetz constant is not great, and it is mentioned here for the sake of completeness.

Another factor of importance in choosing alloys for magnetic work, particularly where alternating current is involved, is the eddy current loss.

It was shown previously that an electric current can produce a magnetic field. In a sense, this process is reversible. If an electrical conductor moves in a magnetic field an electrical current is caused to flow in the conductor. In a generator the magnetic field is stationary and the conductor moves; in an electromagnet the conductor (core) is stationary and the field moves under the action of the alternating current. This causes eddies of electrical current to be set up in the core of the magnet. These currents generate heat and represent a power loss which decreases efficiency.

Eddy Current

The eddy current depends on the area, a design factor, and the resistivity, a material factor. High resistivity is desirable.

Eddy current losses, together with hysteresis loss, make up the core loss which is expressed in watts/lb at a given flux density (10 or 15 kilogausses) at a frequency of 60 cycles/sec. Eddy current losses are proportional to the squares of the thickness, frequency and maximum flux density, and inversely proportional to the resistivity. Thus, the eddy current loss in watts per cc can be

$$P_e = \frac{(\pi \, t \, f \, B_m)^2}{6 \, \rho \, 10^{10}} \tag{5}$$

where

t = thickness of section in cm.
f = frequency in cycles/sec.
B_m = maximum flux density in gausses.
ρ = resistivity in micro-ohm — cm.

Combining this with equation (4) would give the core loss.

There is nothing difficult about using the formulas

given previously. It is merely a question of looking up data, plugging in numbers and grinding out the answer. Equation (5) is usually applied to parts made up of laminations, but can be used for nonlaminated parts also. As the formula shows, the lower the resistivity the higher the eddy current loss, as might be expected.

Armco iron, like all pure metals, has low resistivity and is not recommended for use in alternating current applications. On the other hand, 4 per cent silicon iron is frequently used for such jobs. If we assume a thickness of ¼-in. and a magnetic flux of 10,000 gausses, the following eddy current losses will occur if 60 cycle current is used:

Armco	5.52 watts/cm^2
Malleable	1.85
4% silicon iron	1.16

Probably of more practical interest is the question of holding power of a magnet. Pierce* gives the following formula for the force exerted by a magnet.

$$F = \frac{B^2A}{72} \times 10^{-6} \qquad (6)$$

where

F = force (lb).
B = magnetic flux (maxwells/in.^{2}).
A = pole area (in.^{2}).

*Mechanical Engineering, vol. 80, no. 4, pp. 64-66, April 1958.

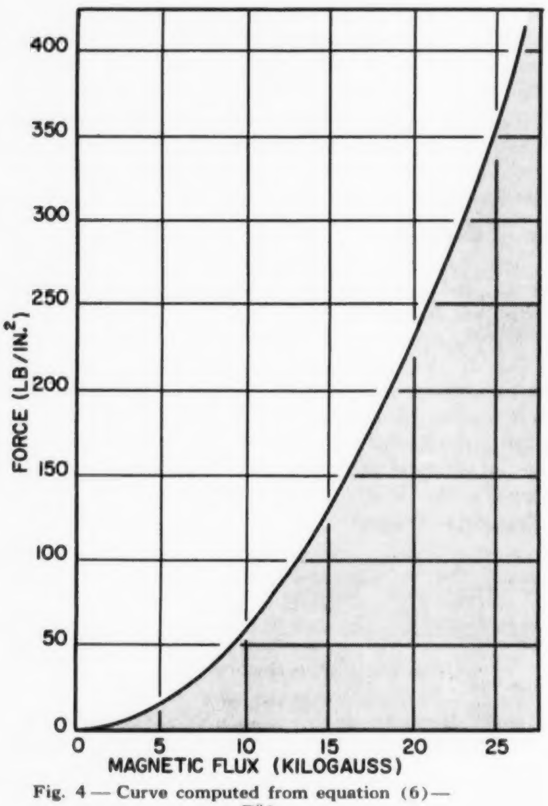

Fig. 4 — Curve computed from equation (6)— $F = \frac{B^2A}{72} \times 10^{-6}$

Here the induced magnetic flux was measured in gausses or kilogausses (1000 gausses) not in maxwells per sq in. Rather than complicate the discussion by introducing new units, the curve of Fig. 4 can be computed from equation (6). Notice that the force is given in lb/sq in. of pole area. In order to show how Fig. 4 can be used, the following illustration will serve.

Example

Suppose a given part is to be made of dynamo steel and of malleable iron. A coil of 100 turns carrying two amperes will energize the mechanism. How large must the pole piece be to exert a force of 150 lb? No air gap is assumed. The coil is 1-in. long.

1) The energizing field will be 200 amp turns which, according to equation (1), is practically 100 oersteds.
2) Using a curve for induced magnetism for each material, the magnetic fluxes can be found. (The required curve for malleable is given in the next section.)

   Dynamo steel – 15.70 kilogausses.
   Malleable – 14.25 kilogausses.

3) Reference to Fig. 4 gives the following forces:

   Dynamo steel – 139 lb/in.^{2}
   Malleable – 117 lb/in.^{2}

4) The following areas are needed to produce a force of 150 lb:

   Dynamo steel – 1.07 sq in.
   Malleable – 1.27 sq in.

An 18 per cent greater area is necessary if malleable is used.

In any electromagnetic application it is desirable to have the force released when the current is shut off. In discussion of the hysteresis loop, it was noted that the magnetic flux does not drop to zero when the magnetizing current drops to zero. This leads to another problem. What is the residual force in the above problem?

Reference to the hysteresis curves of dynamo steel and malleable (also given in the next section) shows the retentivities to be:

Dynamo steel – 10.00 kilogausses.
Malleable – 6.50 kilogausses.

Figure 4 shows the forces corresponding are:

Dynamo steel – 58 lb/in.^{2}
Malleable – 25 lb/in.^{2}

Taking the areas into account, the dragging forces are:

Dynamo steel – 62.5 lb.
Malleable – 29.5 lb.

Figure 4 might also be used for such problems as finding the winding needed to energize the piece given the desired force and the material.

Since this paper is about magnet alloys, examples of calculations of magnetic circuits involving air gaps will not be included. The air gap tends to cut down

the magnetic flux. The ranking of alloys would not change, however, if the calculations are made for circuits with or without air gaps.

METALLURGY OF MAGNETIC ALLOYS

Although nickel and cobalt and some of their alloys have magnetic properties, practically all commercial magnetic materials are iron base.

Pure iron, as represented by armco or electrolytic iron, reacts readily to a magnetic field, and gives a high value of induced magnetism. When the magnetizing current is cut off, the retained magnetism is low. Therefore, for direct current applications pure iron is satisfactory. The electrical resistivity of pure iron is low and, according to equation (5), this means a high eddy current loss in alternating current applications.

In order to overcome this difficulty alloying is indicated. Carbon is the most common alloying element in iron, and carbon will increase the resistivity. Unfortunately, carbon increases the retentivity making the alloy behave like a permanent magnet. It also runs up the Steinmetz constant and, according to equation (4), this means an increase in hysteresis loss. The hysteresis curves of iron-carbon alloys all show the expected increased area. Addition of carbon to iron in effect substitutes one power loss for another. That is why alloys for electromagnets are always low in carbon. The maximum is usually less than 0.10 per cent.

Malleable iron, with its carbon content of about 2.50 per cent, may seem to be an exception. In fully annealed malleable iron all the carbon essentially is in the form of graphite, which is inert magnetically. In effect, all that it does is decrease the active cross-section. The matrix of malleable iron carries all the magnetic lines of force, and the carbon content of this matrix meets the requirements outlined previously.

Iron-Silicon Alloys

Silicon is another common alloying element. It has been found that iron-silicon alloys can be made so that the hysteresis loss and eddy current loss are both low, and still the retentivity and B - H curve are not materially affected. A series of iron-silicon alloys, ranging from 1 per cent to 4 per cent silicon, are commonly used in sheet form for alternating current applications.

Malleable iron, with its silicon content of about 1.25 per cent concentrated in the metallic matrix, fits into this range. Other alloying elements are used for permanent magnets.

Unless a part can be made of sheet or bar stock, there are only two cast alloys in general use. Dynamo steel is low (less than 0.10 per cent) carbon, with about 0.50 per cent silicon. The other cast material is malleable. A comparison of these two cast alloys is given in Table 2. Their magnetic characteristics will be given in detail in the next section.

Current comments can be made on the table. Malleable iron is the only magnetic material which is at the same time an alloy of general application. The magnetic properties of all magnetic alloys vary depending on processing and processing variables. Malleable iron is made by a standard process and is not sensitive to processing variations, so its magnetic properties vary less than those of other alloys.

TABLE 2 — COMPARISON OF CAST MALLEABLE IRON AND DYNAMO STEEL

	Malleable Iron	Dynamo Steel
Magnetic Properties	Relatively constant	Depend on heat treatment
Foundry Characteristics	Good	Poor
Machinability	Good	Poor
Hardness	Soft	Soft
Wear Resistance	Fair to poor	Fair to poor
Availability	Standard alloy	Special alloy

MAGNETIC PROPERTIES

B-H Curve

For malleable iron, like any other magnetic alloy, it is not possible to show the complete picture of its response to magnetic induction with a single graph. The general B - H curve is shown in Fig. 5, which may be used in design calculations. The semi-logarithmic plot is not easily read at its lower end so the arithmetic B - H curve is given in Fig. 6, and can be used in calculations involving small inducing force.

The B - H curves and hysteresis loops of other magnetic materials are seriously affected by processing variables such as rolling or heat treatment. Unless

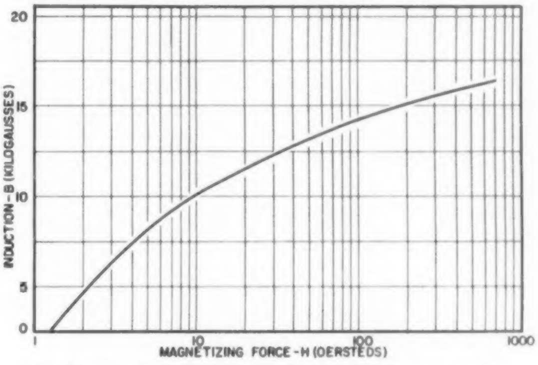

Fig. 5 — General B-H curve for malleable iron which may be used in design calculations.

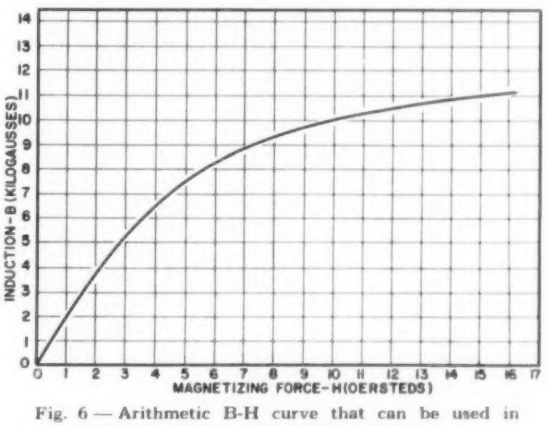

Fig. 6 — Arithmetic B-H curve that can be used in calculations involving small inducing force.

these variables are closely controlled the magnetic properties vary more widely than would be acceptable.

Malleable iron is made for many applications requiring certain properties other than magnetic qualities. In order to obtain the desired properties, a set process with definite controls is followed. When the iron is so produced that it meets the ordinary specifications it will automatically have the best magnetic properties. Since no special handling or treatment is required for malleable iron for magnetic applications, the variability of the product will tend to be less.

Magnetic Variation

There is, of course, some little variation in the magnetic properties of malleable iron due to unavoidable variations in production. However, the effect on magnetic properties is much less than the variability shown by other magnetic alloys. The variation in induced magnetization at low magnetizing forces is practically negligible. At about 30 oersteds, the variation is not more than ±0.5 kilogauss. Even at the highest magnetizing forces the maximum spread is about ±1.5 kilogausses, and this allowance is overgenerous most of the time. Some designers prefer to figure on a range ±1.0 kilogauss.

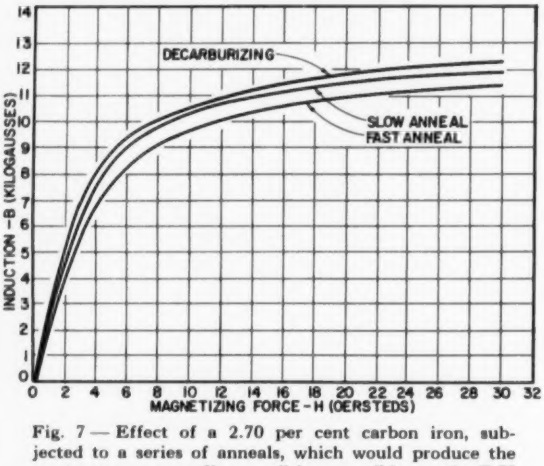

Fig. 7 — Effect of a 2.70 per cent carbon iron, subjected to a series of anneals, which would produce the most extreme annealing conditions possible, on the B-H curve.

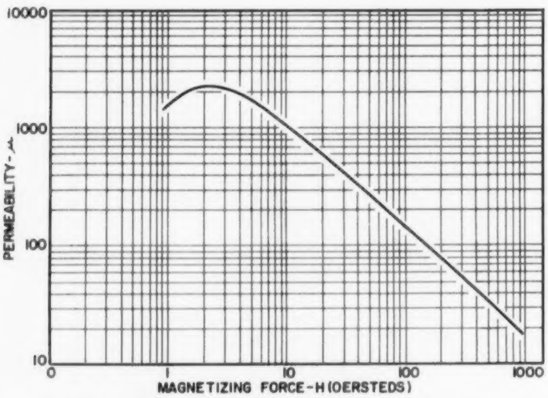

Fig. 8 — Typical malleable iron curve of permeability vs. magnetizing force plotted on log-log paper.

In order to find the sources of the variation an extended series of studies was made at one time, and it was found that the graphite content and annealing practice were the greatest sources of variability.

At low magnetizing force the effect of carbon will not be noticed. At forces of about 25 oersteds up, the *B* value will decrease about 1.4 kiloguasses for an increase of 1 per cent carbon. The carbon caused variation is independent of the magnetizing force. Since the carbon content of white iron is always controlled within ±0.10 per cent, the contribution of carbon to the variation in induced magnetism is small in commercial malleable iron.

A 2.70 per cent carbon iron (standard malleable iron has about 2.50 per cent carbon) was subjected to a series of anneals which would produce the most extreme annealing conditions possible. The effect on the B - H curve is shown in Fig. 7. The variation in *B* is not great, but the curves do not represent commercial practice. In regular production of malleable iron the variation in annealing practice would be far less, and so the variation in magnetic behavior would be less than that shown in Fig. 7.

Saturation Value

The maximum value of induced magnetism in malleable iron is 18,000 gausses. This value is slightly lower than that for other magnetic alloys for rather obvious reasons. The cross-sectional area of a specimen or part is determined by the dimensions of the piece, but, as a photomicrograph will show, part of this area is taken up by graphite, and the metal which carries the lines of force is less than the total cross-section.

Ordinarily parts are not designed to use the saturation value, and if they are the lower value of malleable iron can be compensated by increasing the cross-sectional area.

Permeability

For any magnetic alloy the curve of permeability vs. magnetizing force plotted on log-log paper rises to a maximum at relatively low magnetizing force. The curve for malleable iron, shown in Fig. 8, is typical.

Since graphite occupies space which does not offer passage to many lines of force, it might be expected that the permeability would be affected by the carbon content. At $H = 25$ oersteds, an increase of 1 per cent carbon will drop the permeability about 60 points. Since in malleable iron the carbon is allowed to vary only about 0.1 per cent, the variation in permeability will be extremely small.

Hysteresis

One of the advantages of malleable iron for magnetic applications is its low hysteresis loss. Figure 9 shows a typical hysteresis curve. The hysteresis loss depends on the area included in the loop, and this area in turn depends on the maximum magnetization of a cycle. Steinmetz' equation (4) could be used to compute the hysteresis loss at low magnetizations, but it is preferable to measure the loops. Table 3 gives the measured hysteresis losses corresponding to various maximum magnetization.

Another loss encountered in alternating current work is the eddy current loss. One of the quantities needed to compute this loss (equation 5) is the electrical resistivity. For malleable iron this is 32 microohm–cm.

Coercive Force

For any given metal, the coercivity depends on the previous magnetizing force. The greater this force, the greater will be the coercive force for removing the residual magnetism. Coercivity values for malleable iron range from 1 to 3 oersteds for fairly high magnetization.

Retentivity

The retained magnetism is generally undesirable and depends on the previously induced magnetism. Malleable iron is capable of retaining only a small magnetic strength. Figure 10 shows the retentivity as a function of the previously induced magnetism.

Comparison With Other Magnetic Alloys

There is a long list of alloys which have been used for magnetic purposes. Comparison of malleable with each of them is not possible, so only three were selected.

Pure iron (armco or electrolytic iron) is available in sheet form. Its properties depend to a great extent on processing, and those given below are for iron in a state which would be frequently used.

Four per cent silicon iron also is available in sheet and strip. It belongs to the class sometimes called transformer iron. The properties given are not for grain oriented iron.

Dynamo steel is a cast material, and is included because it is the only cast alloy other than malleable iron which is used currently for magnetic applications.

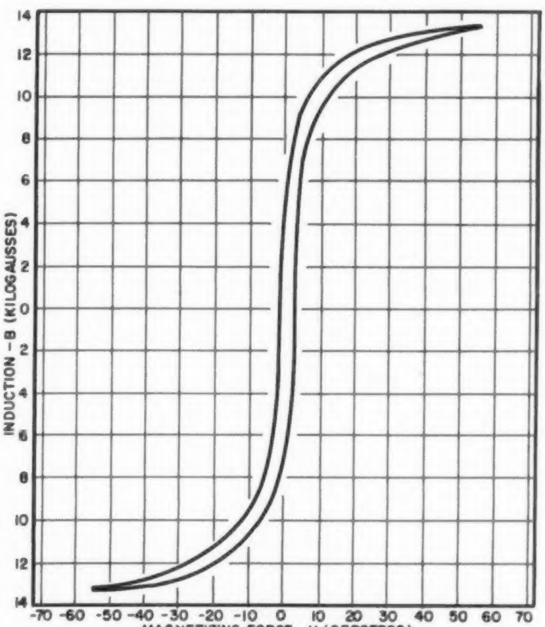

Fig. 9 — Hysteresis curve for malleable iron showing its low hysteresis loss.

TABLE 3 — HYSTERESIS LOSS VS. MAGNETISM

Induced Magnetism B max. (Kilogauss)	Hysteresis Loss (ergs/cc/cycle)
5.45	481
8.63	3752
10.06	4404
11.40	6199
12.70	6862
13.30	7779
14.20	9490
14.60	10542
15.20	11297
15.80	12357

TABLE 4 — MAGNETIC PROPERTIES

Magnetic Property	Malleable	Dynamo	Iron	4% Si Iron
Saturation	18,000	21,400	21,550	19,700
Retentivity (B=15)	6,800	9,000	10,000	—
Max. permeability	2,300	6,000	6,000	7,000
Coercive force	2.0	5.0	1.0	0.5
Hysteresis loss (B=10)	4,400	—	4,000	3,500
Resistivity	32	—	10	60

Some of the magnetic properties of these alloys and malleable iron are given in Table 4.

It can be seen from this comparison that malleable iron has magnetic properties which compare favorably with the properties of other magnetic alloys. No one of these alloys is superior to the rest, and so the final choice of material may depend on other properties which are discussed in the next section.

OTHER PROPERTIES

Tensile Properties

There are two grades of standard malleable iron, but by far the greatest tonnage is produced in the 32510 grade. The minimum tensile properties specified are shown in Table 5.

Dynamo steel in cast form, and most of the wrought forms of magnetic alloys, have tensile properties sim-

TABLE 5 — TENSILE PROPERTIES

Yield Strength, psi	32,500
Tensile Strength, psi	50,000
Elongation, %	10

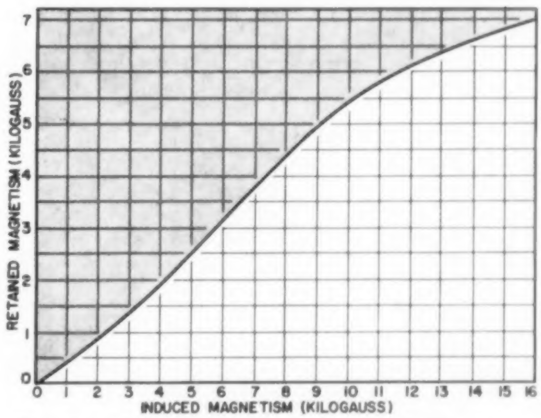

Fig. 10 — Malleable iron retentivity as a function of previously induced magnetism.

ilar to the properties of malleable iron. In fact, design calculations for any of these alloys could be based on a yield strength of 30,000-32,000 psi.

Hardness and Wear Resistance

Since all the magnetic alloys are made up of ferrite, which may or may not contain a little silicon, they are all soft. Malleable iron contains a second phase, graphite, but this does not increase the hardness. All the magnetic alloys have a Rockwell B hardness of approximately 95.

This low hardness means that the wear resistance of magnetic alloys is not particularly good. The hardness of the wrought alloys, and of cast dynamo steel, could be raised by increasing the carbon content and heat treating. The normal heat treatment which produces malleable iron could be changed slightly to produce pearlitic malleable, which is harder than standard malleable. These changes would produce more wear resistant metals, but would do so at the expense of the magnetic properties.

Any designer who has a magnetic application should recognize that the magnetic alloys from which he must choose are all soft, and if wear is a problem he must provide means of protecting against wear.

Malleable iron is the only magnetic material which will respond at all to flame hardening, but the result is obtained by recombining carbon and so the magnetic properties will suffer. For the same reason, carburizing is not recommended.

The use of hard steel wear plates is not a good idea because they form part of the magnetic circuit and act like permanent magnets, and increase core loss and retentivity.

The best solution is to cover the surface with a nonmagnetic, wear resistant material like a hard chromium electroplate.

Foundry Characteristics

There are designs which, because of their shape, are best made as castings. If the alloy must be a magnetic material, the choice would be between malleable iron and cast dynamo steel.

The foundry characteristics of the two metals are quite different. Malleable iron can be produced in much thinner sections than cast dynamo steel. If the casting is not too long malleable iron can be cast 1/8-in. thick, and the dynamo steel would need to be about twice that thickness.

At the other extreme, there is no limit on the thickness which can be cast in dynamo steel, but malleable is limited by the occurrence of mottling in large sections. However, sections which would mottle are larger than would generally be used for magnetic work, because the eddy currents would be quite high in such large sections.

Aside from the foundryman's problems in dealing with dynamo steel, there is another advantage to malleable iron. The production of malleable iron is a standard thing. Dynamo steel, in contrast, is a tailored steel which requires some special handling.

Machinability

Whether the design is cast or cut from bar stock, there is likely to be some machining. Casting minimizes machining, but even so machinability is important.

Pure iron, the silicon irons and cast dynamo steel have one thing in common—their machinability is terrible. They tend to load the tool and to tear.

Malleable iron, on the other hand, is one of the most easily machined alloys available. It is much easier to machine than the free cutting steels like S.A.E. 1112, which are often used as standards of machinability.

CONCLUSIONS

As far as strength and hardness is concerned, all the magnetic alloys are alike. Malleable iron has the advantage of being a cast form, readily available and easily machined.

APPENDIX

Although the units used in this bulletin are commonly used in magnetic work, there are other units which are preferred by some workers. The following conversion table is given so that the confusion of including these other units in the discussion could be avoided.

Ampere – turns/cm × 1.257 = oersteds
Ampere – turns/in. × 0.495 = oersteds
Gilberts/cm × 1 = oersteds
Lines/cm^2 × 1 = gausses
Lines/$in.^2$ × 0.155 = gausses
Maxwells/cm^2 × 1 = gausses
Maxwells/$in.^2$ × 0.155 = gausses
Webers/cm^2 × 1 × 10^8 = gausses
Webers/$in.^2$ × 1.55 × 10^7 = gausses

ELECTRICAL CONDUCTIVITY OF SAND-CAST COPPER-BASE ALLOYS

By D. G. Schmidt and F. L. Riddell

ABSTRACT

The electrical conductivities of over 100 various sand-cast copper-base alloys have been determined. Since many tensile specimens were being tested daily, the standard 0.505 in. diameter test specimen was used for the electrical conductivity measurements. Data list electrical conductivities for the standard American Society for Testing Materials cast copper-base alloys, plus many other cast copper-base alloys. The effect of alloying elements on the electrical conductivities of the various classes of sand-cast copper-base alloys is illustrated.

INTRODUCTION

Copper or alloyed copper castings are used in the electrical industry for their current carrying characteristics. However, sound copper castings, with a minimum of 85 per cent I.A.C.S. electrical conductivity, are difficult to make. The ordinary deoxidizers, such as silicon, aluminum, zinc and phosphorus, cannot be used, because residual amounts lower the electrical conductivities drastically (Fig. 1).

Cast copper is soft and low in strength. Improved mechanical properties with good conductivity (40 to 80 per cent I.A.C.S.) may be obtained with heat treated alloys containing silicon, cobalt, chromium, nickel and beryllium in various combinations. However, these alloys are expensive and less readily available than the standard copper-base foundry alloys, and due to the highly oxidizable nature of their alloying elements (silicon, chromium and beryllium), extra care is required in melting and pouring.

In many instances, where design permits the use of lower electrical conductivities, the standard copper-base foundry alloys may be used. Numerous inquiries, as to the electrical conductivities of the various copper-base foundry alloys, were received, and the writers were unable to give factual data from the available literature.

The *Brass and Bronze Ingot Institute Manual*[2] lists the electrical conductivities for several of the standard alloys, but the authenticity of these figures has never been verified. Some conductivity figures are listed in various manuals published by the manufacturers of copper-base alloys (both in ingot form and as castings). However, no data as to type of specimen, exact analyses or other pertinent information are listed.

Smith and Palmer[3] report the electrical and thermal conductivities of nine various cast copper alloys.

Kura and Lang[4] report the electrical conductivities of three alloys— 85 Cu, 5 Sn, 5Pb, 5Zn; 88 Cu, 6 Sn, 2 Pb, 4 Zn and 80 Cu, 10 Sn, 10 Pb — at five different temperatures. Due to the scarcity of authenticated information in the literature, the authors' company's research laboratory started a program to determine the electrical conductivity of the many commercial copper-base foundry alloys.

RESISTANCE MEASURING EQUIPMENT

A general purpose Kelvin bridge was used to make the resistance measurements. This Kelvin bridge has a range of 0.00001 to 1 ohms, without estimating fractions of scale divisions. By adding a vernier scale to the equipment, readings to the nearest 0.000001 ohm were possible. The resistivity measurements used for this report are estimated to be accurate within ± 0.5 per cent.

Since the measurement of electrical conductivity is a daily routine test in the company's research laboratory, a constant temperature oil bath was not used. Instead, the test specimens were allowed to reach ambient temperature before testing, with the temperature being recorded for each test, and a temperature correction made in the calculations.

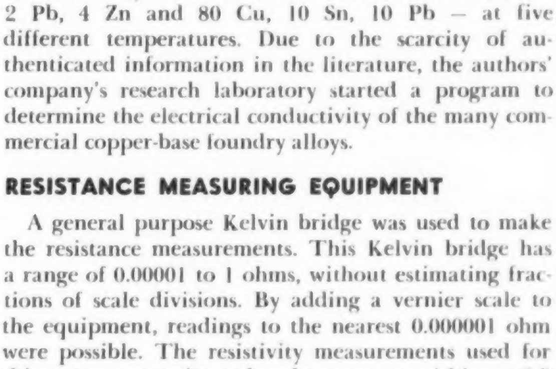

Fig. 1 — Effect of alloying elements on electrical conductivity of copper, ref. 1.

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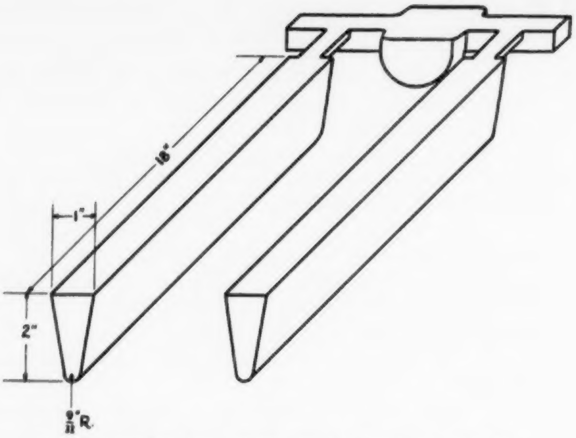

Fig. 2 — Wedge bar casting used for 18 in. x ⅜-in. diameter conductivity specimen.

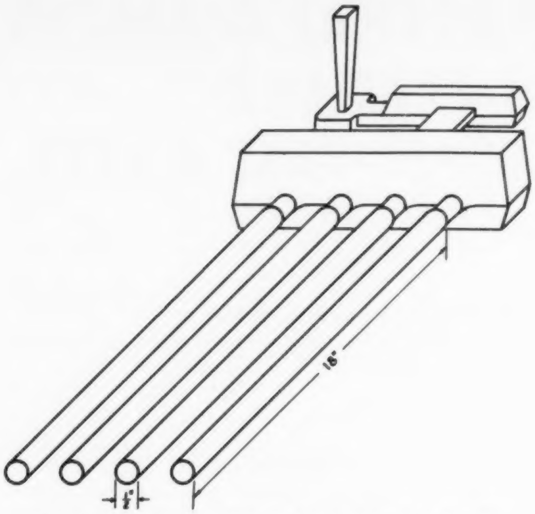

Fig. 3 — Rod bar casting used for 18 in. x ⅜-in. diameter conductivity specimen.

The formula used for determining the electrical conductivity was:

$$C = \frac{0.017241}{\frac{R}{L}\frac{D^2\pi}{4} + 0.000068(20\text{-}t)} \times 100$$

where:

C = electrical conductivity expressed as a per cent of the International Annealed Copper Standard.

0.017241 = the resistance in ohms of the International Annealed Copper Standard; one meter long and 1 sq mm in cross-section at 20 C (68 F).

R = resistance of the sample between potential points.

D = diameter of the sample in mm.

L = distance between potential points in meters.

t = temp. in degrees C of the sample when the resistance is measured.

0.000068(20-t) = temperature correction for reducing resistance at the temperature of measurement to resistance at 20 C (68 F).

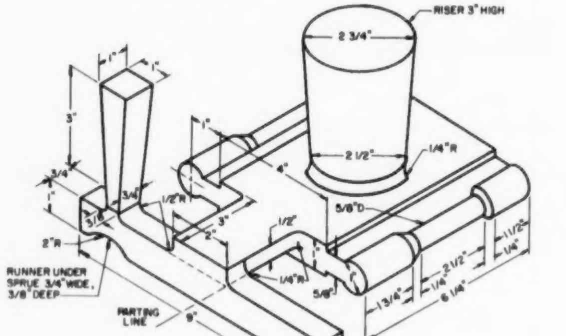

Fig. 4 — Double horizontal full-web type test bars (A.S.T.M. B208-49T).

TEST SPECIMEN SELECTION

In order to obtain relatively high resistance readings, a long bar of small cross-section was originally used. The first test bars poured were wedges, 18 in. long, 2 in. deep and 1 in. across the top, with a $^9/_{32}$-in. radius on the bottom (Fig. 2). The test specimen was then cut from the bottom portion of the casting and machined to a 0.350 to 0.375 in. diameter rod. This wedge-type bar gave results that were not reproducible from one heat to another of the same material. In addition, the test specimen was unwieldy, as far as removing from the wedge casting and then machining.

Figure 3 shows the second type test casting used. This was a ½-in. diameter rod, 18 in. long, which was then machined to 0.350 to 0.375-in. diameter rod. Most of these rod castings exhibited center-line shrinkage, and it was felt that for consistent and accurate results, the test specimens should be as sound as possible.

Since one of the functions of the research laboratory is to determine mechanical properties of production heats made for shipment, it was felt that these same tensile test bars could possibly be used for the electrical conductivity measurements. Sound test bars could readily be obtained from the horizontal ⅝-in. Web-Webbert test bar casting, Fig. 4 (Fig. 3 A.S.T.M. B-208-56). This bar is machined to 0.505-in. diameter with a 2½-in. length of uniform cross-section.

To determine if the standard 0.505 in. diameter bar would prove satisfactory, a ¾-in. diameter and 12 in. long piece of wrought brass, of the following composition was tested for conductivity.

Copper,%	56.88
Tin,%	0.07
Lead,%	0.75
Iron,%	1.13
Nickel,%	1.37
Zinc,%	Remainder

From this 12 in. long rod, two standard 0.505 in.

diameter tensile test bars were machined, and the conductivity measured over a 2-in. length. Table 1 lists the results of this test.

From the close agreement between the conductivity of the longer bar and the standard 0.505 in. diameter test bar, it was decided that electrical conductivity measurements could be accurately determined on the standard 0.505 in. diameter tensile test specimen.

FOUNDRY PROCEDURE

The melting charges consisted of all ingot, or ingot plus foundry returns of known composition. The charges were melted in a No. 60 crucible, in a gas-fired crucible furnace. In all heats, the atmosphere above the melt was of an oxidizing nature.

In the case of the copper/tin/lead/zinc alloys, 15 per cent phosphor copper was used for deoxidation just prior to pouring (usually 2 oz per 100 lb of metal). Zinc additions were made to those alloys requiring replacement for that lost on melting. A proprietary alloy for deoxidation and fluidization of the nickel silvers was used. No special additions were required for the aluminum or silicon bronzes.

A match plate of the test bar pattern, Fig. 4 (Fig. 3 A.S.T.M. B-208-5), was used to make the molds. The molds were made from a natural green sand, having the following average properties:

Green Strength, psi ....5.5 - 6.0
Permeability .... 35 - 40
Moisture,% ....5.5 - 6.5

The melts were poured at temperatures consistent with good practice for each alloy, to obtain optimum properties. In almost all cases, the test bar castings were shaken out one-half hour after pouring.

DISCUSSION OF RESULTS

The electrical conductivities, as determined by the research laboratory, and by other investigators, are listed in Table 2. The alloys listed in this table are those standard copper-base alloys, both in ingot form

TABLE 1 — CONDUCTIVITY TEST RESULTS

	0.75 in. diameter bar	0.505 in. tensile bar	0.505 in. tensile bar
Temp., C (F)	24.5 (76.1)	23.3 (73.9)	23.3 (73.9)
Diameter, mm	19.0	12.8	12.8
Length, meters	0.18	0.051	0.051
Resistance, ohms	0.000058	0.000036	0.000036
I.A.C.S., %	18.91	18.95	18.95

TABLE 2 — ELECTRICAL CONDUCTIVITY OF THE STANDARD A.S.T.M. COPPER-BASE ALLOYS

Class	A.S.T.M. Specification			% I.A.C.S.				
	Alloy	Ingot	Castings	H.K. & Co.	B.B.I.I. Manual	Mfg. Literature	Smith and Palmer	Kura and Lang
Tin bronze	88-10-0-2	B30 (1A)	B143 (1A)	10.7		10-12	10.9	
	88-8-0-4	(1B)	(1B)	12.3		14-16	11.6	
Leaded tin bronze	88-6-2-4	B30 (2A)	B143 (2A)	13.9	13-15	13-15		14.3
	87-8-1-4	(2B)	(2B)	12.3		10-12		
High lead tin bronze	80-10-10	B30 (3A)	B144 (3A)	11.0		7-12		10.1
	83-7-7-3	(3B)	(3B)	12.3		10-14		
	85-5-9-1	(3C)	(3C)	14.9				
	78-7-15	(3D)	(3D)	11.7			9.8	
Leaded red & semi-red brass	85-5-5-5	B30 (4A)	B145 (4A)	15.0	13-16	13-16		15.1
	83-4-6-7	(4B)	(4B)	15.3		16.0		
	81-3-7-9	(5A)	(5A)	16.5	18.0	18.0		
	76-3-6-15	(5B)	(5B)	16.6				
Leaded yellow brass	72-1-3-24	B30 (6A)	B146 (6A)	18.7	15-22	15-22		
	68-1-3-28	(6B)	(6B)	19.5	18-25	18-25		
	63-1-1-35	(6C)	(6C)	21.9	20-26	20-24	23.4	
Leaded high strength yellow brass	60,000# T.S.	B30 (7A)	B147 (7A)	18.5	20-24			
High strength yellow brass	65,000# T.S.	B30 (8A)	B147 (8A)	22.7	16-20	16-20	21.6	
	90,000# T.S.	(8B)	(8B)	7.9		12-14		
	110,000# T.S.	(8C)	(8C)	8.0	10-14	10-14		
Aluminum bronze	88-3-9	B30 (9A)	B148 (9A)	12.5	12-14			
	89-1-10	(9B-AC)*	(9B-AC)*	15.0	12-15	12-15		
		(9B-HT)**	(9B-HT)**	13.5	13.8	13.8		
	86-4-10	(9C-AC)*	(9C-AC)*	13.7	12.0	12.0		
		(9C-HT)**	(9C-HT)**	12.0				
	81-4½-10-4½	(9D-AC)*	(9D-AC)*	9.3				
		(9D-HT)**	(9D-HT)**	8.5				
Leaded nickel bronze	55-2-9-22-12	B30 (10A)	B149 (10A)	5.7	5-7		5.9	
	64-4-4-8-20	(11A)	(11A)	5.4	4.5-5.5		5.0	
	66-5-1-3-25	(11B)	(11B)	4.7	4.5			
Silicon bronze			B198 (12A)	6.0		6.0	4.9	
Silicon brass			B198 (13A)	6.5			6.1	
			(13B)	5.5		8.0		

*Sand cast.
**Heat treated — 1650 F (905 C), 2 hr, water quenched, followed by 1100 F (595 C), 1 hr, water quenched.

and as castings, as specified by the A.S.T.M. In most cases, there was agreement between the electrical conductivities determined in this work and those determined by other investigators.

The electrical conductivities of the various classes of sand-cast copper-alloys are listed in Table 3 to Table 10, inclusive.

In a paper by A. L. Norbury,[5] where the effects of several elements on the electrical conductivity were determined, it was found that the specific resistivity was raised approximately 1.3 times for each 1.0 per cent of nickel or tin added to copper. Since tin and nickel have approximately the same effect on electrical conductivity, the data from Tables 3, 4, 5 and 6 are illustrated in Fig. 5, where electrical conductivity is plotted against the per cent tin plus nickel.

For the alloys considered in Fig. 5, the effects of zinc, lead and the minor elements appear to be relatively small, as most of the points lie on or close to the average curve. As the tin and nickel are in-

TABLE 3 — ELECTRICAL CONDUCTIVITY OF SAND-CAST TIN BRONZES AND LEADED TIN BRONZES

Alloy Nominal Composition	Composition, per cent								Average % I.A.C.S.
	Cu	Sn	Pb	Zn	Fe	Sb	Ni	P	
89-11-0-0	89.0	10.6	trace	trace	0.03	trace	trace	0.24	9.6
88-10-2-0	87.5	9.3	2.2	0.3	0.02	0.09	0.4	0.02	11.0
88-10-0-2	86.8	10.1	0.2	2.5	0.06	0.03	0.3	0.02	10.9
88-8-0-4	87.6	8.2	0.15	3.8	0.08	0.03	0.1	0.01	12.4
88-6-2-4	88.3	6.0	1.8	3.1	0.08	0.10	0.6	0.01	13.8
88-5-2-5	87.0	5.3	2.2	4.5	0.15	0.03	0.5	0.01	14.1
87-11-1-0-1 (Ni)	87.6	10.2	1.0	0.3	0.01	0.03	0.9	0.01	11.1
87-11-1-0-1 (Ni)	87.0	10.5	1.0	0.3	0.01	0.03	0.9	0.19	10.1
87-11-1-0-1 (Ni)	86.0	10.6	1.1	0.7	0.10	0.03	1.0	0.31	9.2
87-11-0-1-1 (Ni)	85.9	11.5	0.2	1.0	0.03	0.03	1.3	0.01	10.1
87-10-1-2	86.7	9.7	0.9	2.1	0.10	0.10	0.4	0.02	10.8
87-10-2-1	86.4	9.7	1.6	1.6	0.03	0.10	0.5	0.01	11.0
87-8-1-4	87.5	8.0	0.7	3.3	0.15	0.10	0.2	0.02	12.3
88-5-0-2-5 (Ni)	87.1	5.4	0.01	2.4	0.03	0.02	5.1	0.01	11.5
88-5-0-2-5 (Ni)		(Cooled in sand to room temp.)							11.9
88-5-0-2-5 (Ni)		(H.T. — 1400 F - 4 hr - oil quench + 600 F - 5 hr - air cool)							14.8
87-5-1-2-5 (Ni)	86.5	5.1	1.1	2.1	0.10	0.02	5.0	0.02	12.0
87-5-1-2-5 (Ni)		(H.T. — 1400 F - 5 hr - air cool + 600 F - 7 days - air cool)							15.7
85-9-1-0-5 (Ni)	83.6	9.2	1.2	0.4	0.1	0.02	5.2	0.01	10.3
84-16-0-0	83.9	15.4	0.05	0.3	trace	0.02	0.02	0.01	8.5

TABLE 4 — ELECTRICAL CONDUCTIVITY OF SAND-CAST HIGH LEAD TIN BRONZES

Alloy Nominal Composition	Composition, per cent								Average % I.A.C.S.
	Cu	Sn	Pb	Zn	Fe	Sb	Ni	P	
87-4-8-1	86.4	4.1	8.0	0.9	0.02	0.15	0.30	0.01	16.4
85-5-9-1	83.4	4.5	9.8	1.4	0.03	0.20	0.50	0.02	14.9
84-8-8-0	83.3	7.4	8.1	0.5	0.02	0.20	0.25	0.01	11.8
84-4-8-4	84.4	4.0	8.3	2.7	0.10	0.10	0.40	0.01	16.9
83-7-7-3	82.8	6.8	7.5	2.1	0.10	0.15	0.60	0.01	12.4
81-8-9-0-2 (Ni)	82.2	7.0	9.0	0.2	0.01	0.20	1.25	0.01	12.1
80-10-10	79.7	8.8	10.1	0.7	0.01	0.20	0.35	0.01	11.0
78-7-15	77.4	6.8	14.5	0.7	0.03	0.30	0.25	0.02	11.6
75-3-20-0-2 (Ni)	75.0	3.4	18.4	0.3	0.05	0.15	2.20	0.01	14.2
75-13-10-0-2 (Ni)	74.8	13.1	9.4	0.5	0.02	0.15	2.00	0.01	8.6
73-5-22	73.1	4.2	21.9	0.1	0.01	0.05	0.50	0.01	14.1
66-2-32	66.1	1.9	31.0	0.1	0.01	0.05	0.50	0.01	17.8

TABLE 5 — ELECTRICAL CONDUCTIVITY OF SAND-CAST LEADED RED BRASS AND LEADED SEMI-RED BRASS

Alloy Nominal Composition	Composition, per cent								Average % I.A.C.S.
	Cu	Sn	Pb	Zn	Fe	Sb	Ni	P	
93-1-2-4	93.1	0.9	2.5	3.0	0.05	0.05	0.30	0.01	32.4
85-5-5-5	84.6	4.5	5.3	4.6	0.10	0.15	0.65	0.02	15.0
83-4-6-7	82.4	3.8	6.4	6.5	0.20	0.20	0.50	0.02	15.2
83-3-3-11	82.9	3.0	2.9	10.1	0.20	0.15	0.70	0.01	16.7
81-3-7-9	81.2	2.6	7.2	8.0	0.25	0.15	0.50	0.02	16.6
80-5-5-5-5 (Ni)	79.9	4.8	5.4	4.6	0.30	0.15	4.80	0.02	11.1
78-3-7-11-1 (Ni)	79.7	2.6	6.2	10.0	0.25	0.15	1.10	0.01	16.0
76-3-6-15	74.6	3.2	7.3	14.3	0.15	0.10	0.30	0.01	16.6
76-2½-6½-15	76.7	2.4	6.5	13.6	0.30	0.10	0.35	0.02	17.7
76-2-6-16	75.3	2.1	6.9	15.0	0.15	0.10	0.35	0.03	19.0
76-1-6-17	75.9	1.1	7.6	14.8	0.15	0.10	0.30	0.02	21.3

TABLE 6 — ELECTRICAL CONDUCTIVITY OF SAND-CAST YELLOW BRASS

Alloy Nominal Composition	Composition, per cent							Average % I.A.C.S.
	Cu	Sn	Pb	Fe	Sb	Ni	Others	
72-1-5-22	72.8	1.6	4.7	0.4	0.2	0.6		18.6
68-1-3-28	68.1	1.0	2.3	0.3	0.1	0.2		19.6
64-0-0-35-1	64.5	0.05	0.1	0.1	trace	trace	1.1 Si	15.1
63-1-1-35	61.9	0.6	1.0	0.2	0.05	0.3		22.0
63-1-1-35	61.8	0.7	1.1	0.2	0.05	0.1	0.25 Al	21.8
60-1-0-38-1	59.9	1.0	0.04	0.01	0.05	0.3	1.15 Al	23.7
60-0-3-37	61.5	0.1	2.8	0.10	trace	trace	0.06 Al	25.7
60-0-1-38-1	59.5	trace	1.0	0.30	0.01	0.05	1.1 Al	26.5
60-0-0-40	60.9	0.05	0.1	0.4	trace	0.05	0.8 Al	24.9
60-0-2-38	58.7	0.05	2.2	0.1	trace	0.02		26.4
58-1-1-40	58.6	1.0	0.8	0.5	0.01	0.10	0.5 Al	23.3
52-0-0-48	52.4	0.1	0.05	0.01	trace	trace	0.4 Al	35.8

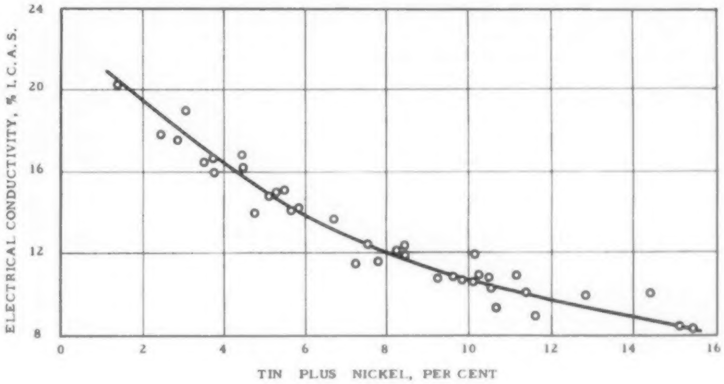

Fig. 5 — Effect of tin plus nickel on the electrical conductivity of tin bronzes, leaded tin bronzes, high lead tin bronzes, leaded red brasses and leaded semi-red brasses.

creased, the electrical conductivity decreases. The data for the 87-11-1-0-1 alloy show that as the phosphorus is increased, the conductivity decreases (Fig. 6).

The electrical conductivities of various sand-cast yellow-brass alloys are listed in Table 6. In the range of copper used in the yellow brasses, i.e., 50 to 75 per cent copper, Fig. 7 shows that as the copper is increased, the electrical conductivity decreases. Here again, tin shows the effect of lowering the conductivity. It is surprising to note that aluminum, which is normally added to many of the yellow brasses for increased fluidity, has not appreciably affected the conductivity.

Table 7 lists the electrical conductivity of the sand-cast high strength yellow brasses. Manganese bronzes, Table 11 and Fig. 8 show the effect of copper on the electrical conductivity of a manganese bronze type alloy. For this alloy, as the copper is increased, the conductivity decreases.

The electrical conductivities for the sand-cast aluminum bronzes, both in the as-cast and heat treated conditions, are listed in Table 8. Heat treating at 1650 F (905 C) for 2 hr, water quenching, followed by 1100 F (595 C) for 1 hr and water quenching, lowers the electrical conductivity. Table 12 and Fig. 9 show the effect of aluminum on the electrical conductivities of three standard sand-cast aluminum bronzes. Within the range of aluminum used, as the aluminum content is increased, the electrical conductivity is also increased.

Table 9 lists the electrical conductivity for the sand-cast nickel-silver and copper-nickel alloys. Due to the many different combinations of alloying elements used in these alloys, little correlation of data is possible. The trend appears to be that as nickel increases, electrical conductivity decreases.

Table 10 lists the electrical conductivities for the sand-cast silicon-bronzes and silicon brasses. Table 13 and Fig. 10 show the effect of silicon on the electrical conductivity of three standard copper-silicon alloys. Within the range of silicon used for these alloys, an increase in silicon decreases electrical conductivity. An increase of approximately 10 per cent zinc has not appreciably lowered the electrical conductivity of the

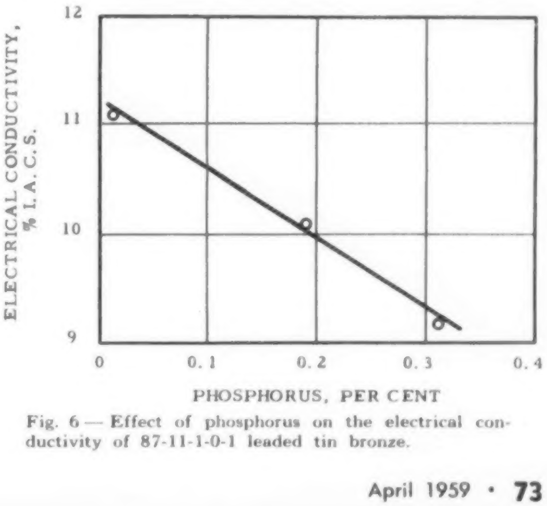

Fig. 6 — Effect of phosphorus on the electrical conductivity of 87-11-1-0-1 leaded tin bronze.

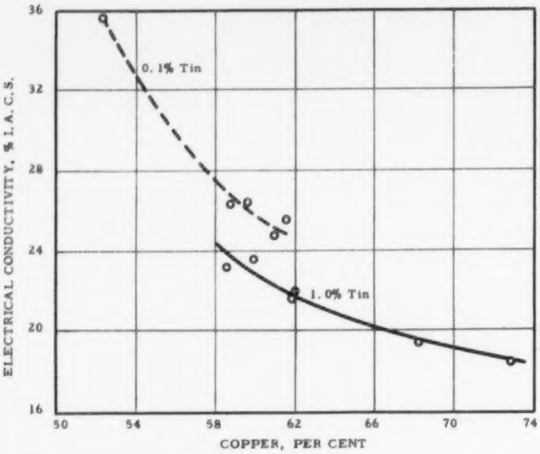

Fig. 7 — Effect of copper and tin on the electrical conductivity of yellow brass alloys.

TABLE 7 — ELECTRICAL CONDUCTIVITY OF SAND-CAST HIGH-STRENGTH YELLOW BRASS (MANGANESE BRONZE)

Alloy	Composition, per cent					Average % I.A.C.S.
	Cu	Fe	Al	Mn	Others	
60,000 psi T.S.	58.8	0.9	0.7	0.4	0.6 Sn 0.8 Pb	19.3
65,000 psi T.S.	58.4	1.0	1.0	0.25		21.9
Nickel Manganese Bronze	53.9	1.6	1.3	3.2	3.2 Ni	9.1
80,000 psi T.S.	58.5	1.6	1.7	1.0		16.7
90,000 psi T.S.	59.1	1.6	2.2	1.7		14.5
90,000 psi T.S.	64.0	2.2	3.9	4.0		7.4
90,000 psi T.S.	58.4	2.0	3.1	0.1		24.0
90,000 psi T.S.	66.8	2.5	5.4	3.9		7.4
110,000 psi T.S.	62.5	2.7	6.0	3.8		7.9

Fig. 8 — (Right) Effect of copper on the electrical conductivity of a manganese bronze alloy.

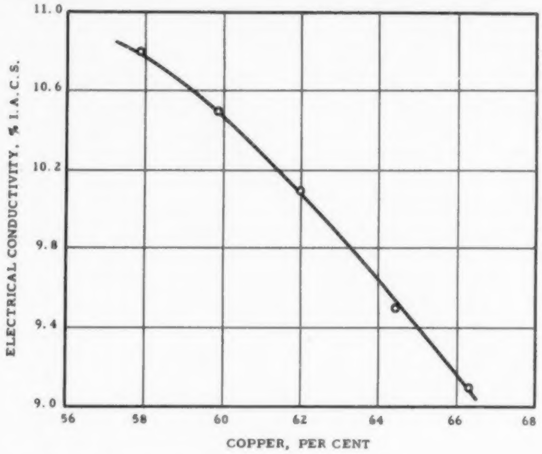

TABLE 8 — ELECTRICAL CONDUCTIVITY OF SAND-CAST ALUMINUM BRONZES

Alloy Nominal Composition	Condition of Bars	Composition, per cent					Average % I.A.C.S.
		Cu	Fe	Al	Mn	Ni	
Copper-Aluminum							
95-5	As-cast	94.8	0.01	5.1	trace	0.03	17.0
90-10	As-cast	88.8	0.10	11.0	0.01	trace	13.6
88-12	As-cast	87.9	0.10	11.8	0.01	0.05	20.3
Copper-Iron-Aluminum							
90-1-9	As-cast	89.1	1.5	9.2	0.10	0.10	12.9
89-1-10	As-cast	88.2	1.4	10.1	0.01	0.03	15.1
89-1-10	Heat treated*	88.2	1.4	10.1	0.01	0.03	12.7
88-3-9	As-cast	87.4	3.4	8.9	0.06	0.20	12.2
86-4-10	As-cast	85.9	3.4	10.4	0.06	0.05	14.6
86-4-10	Heat treated*	85.9	3.4	10.4	0.06	0.05	12.4
84-4-12	As-cast	84.4	3.5	11.8	0.05	0.05	16.8
81-5-14	As-cast	80.8	4.8	14.0	0.20	0.05	10.8
Copper-Iron-Aluminum-Nickel							
88-1-10-1	As-cast	88.1	0.8	9.9	0.01	1.1	13.4
87-1-10-2	As-cast	87.1	0.9	9.8	0.06	2.1	12.2
84-4-10-2	As-cast	83.4	3.9	10.4	0.1	2.1	11.0
84-4-10-2	Heat treated*	83.4	3.9	10.4	0.1	2.1	10.2
81-3-11-5	As-cast	81.5	2.9	10.5	0.1	4.9	9.4
81-4-11-4	As-cast	81.6	4.0	10.4	0.1	3.8	10.3
80-5-10-5	As-cast	79.5	4.8	10.2	0.1	5.2	8.9
80-5-10-5	Heat treated*	79.5	4.8	10.2	0.1	5.2	8.4
76-5-14-5	As-cast	76.7	4.4	14.0	0.2	4.6	12.6
Copper-Iron-Aluminum-Manganese							
85-3-11-1	As-cast	85.3	2.6	10.7	1.1	0.05	10.5
85-3-11-1	Heat treated*	85.3	2.6	10.7	1.1	0.05	9.4
Copper-Iron-Aluminum-Nickel-Manganese							
80-5-9-5-1	As-cast	78.9	4.5	9.6	1.4	5.4	6.9
79-5-9-5-2	As-cast	78.9	4.8	9.1	2.1	4.8	6.5
78-5-9-5-3	As-cast	77.3	4.8	9.6	3.2	4.9	5.8

*Heat Treatment — 1650 F (905 C), 2 hr. water quench, plus 1100 F (595 C), 1 hr. water quench.

TABLE 9 — ELECTRICAL CONDUCTIVITY OF SAND-CAST NICKEL SILVERS AND COPPER-NICKEL ALLOYS

Alloy Nominal Composition	Composition, per cent							Average % I.A.C.S.
	Cu	Sn	Pb	Zn	Fe	Ni	Others	
9% Nickel Silver	50.6	1.4	0.1	35.3	1.1	10.5	1.0 Al	9.4
12% Nickel-Copper	84.8	0.01	0.01	0.01	0.9	12.0	1.2 Al 0.7 Mn	10.1
12% Nickel Silver	64.5	2.6	6.3	14.3	0.6	11.4		6.5
12% Nickel Silver	54.7	1.9	9.9	19.7	1.2	12.4		5.7
15% Nickel Silver	63.1	2.2	7.3	10.5	0.5	16.0		5.4
18% Nickel-Copper-Zinc	64.8	trace	trace	8.5	1.0	17.7	8.0 Al	9.3
20% Nickel Silver	65.0	3.7	3.8	6.0	1.0	20.2		5.0
20% Nickel-Copper-Zinc	57.6	0.3	0.5	21.0	1.2	19.5	0.25 Al	4.7
23% Nickel-Copper-Tin	63.6	10.2	0.05	1.8	0.8	23.4		5.6
25% Nickel Silver	59.5	1.3	2.0	10.9	1.6	24.4		4.2
25% Nickel Silver	65.7	4.7	0.9	2.8	0.8	25.0		4.6
28% Nickel-Copper	66.8	trace	trace	trace	4.3	28.1	0.6 Mn	5.2
30% Nickel-Copper	68.8	trace	trace	trace	0.5	29.3	0.7 Mn 0.7 Si	4.6

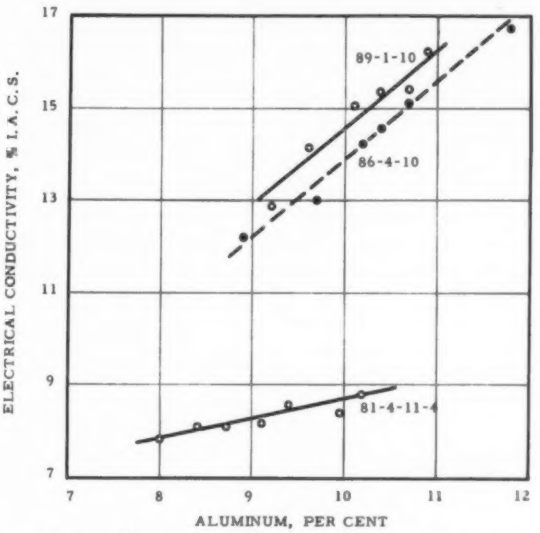

Fig. 9 — Effect of aluminum on the electrical conductivity of aluminum bronze alloys.

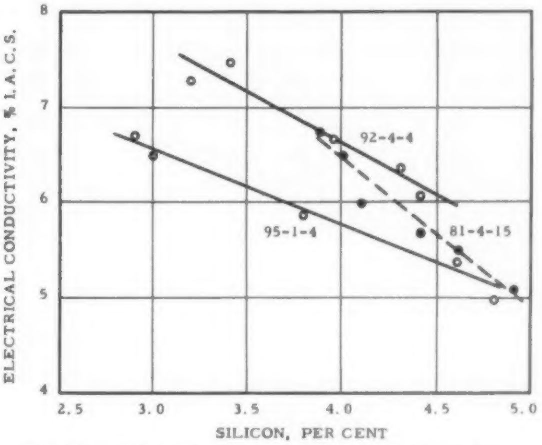

Fig. 10 — Effect of silicon on the electrical conductivity of silicon bronze alloys.

TABLE 10 — ELECTRICAL CONDUCTIVITY OF CAST SILICON BRONZES AND SILICON BRASSES

Alloy Nominal Composition	Composition, per cent						Average % I.A.C.S.
	Cu	Fe	Mn	Si	Zn	Others	
96-1-3	95.8	0.15	1.1	3.0	0.1		6.5
95-1-4	94.7	0.2	1.1	3.8	—		5.9
95-1-4	95.0	0.1	—	3.7	0.3	0.8 Sn	6.6
92-4-4	92.0	0.1	—	4.4	3.5		6.1
91-4-3-1½	90.4	1.2	—	3.2	4.6	0.4 Al	7.4
91-2-7	90.5	0.1	—	2.2	0.2	7.1 Al	8.8
86-2-7-5	85.9	0.1	0.02	2.0	4.9	7.0 Al	7.3
90-4-2-4	90.2	0.2	0.01	1.4	3.6	4.5 Al	10.7
81-4-15	81.9	0.2	0.01	4.0	13.9		6.5

TABLE 11 — COPPER EFFECT ON ELECTRICAL CONDUCTIVITY OF MANGANESE BRONZE

Composition, per cent				% I.A.C.S.
Cu	Fe	Al	Mn	
57.9	2.4	2.9	2.6	10.8
59.9	2.1	2.8	2.5	10.5
62.0	2.0	2.9	2.5	10.1
64.4	1.9	2.8	2.5	9.5
66.3	1.9	2.9	2.5	9.1

TABLE 12 — ALUMINUM EFFECT ON ELECTRICAL CONDUCTIVITY OF SAND-CAST ALUMINUM BRONZES

Alloy	Composition, per cent				% I.A.C.S.
	Cu	Fe	Al	Ni	
89-1-10	89.1	1.5	9.2		12.9
	89.0	1.3	9.6		14.2
	88.2	1.4	10.1		15.1
	87.8	1.5	10.4		15.4
	87.6	1.4	10.7		15.4
	87.3	1.5	10.9		16.3
86-4-10	87.4	3.4	8.9		12.2
	86.5	3.5	9.7		13.0
	86.4	3.3	10.2		14.3
	85.9	3.4	10.4		14.6
	85.7	3.3	10.7		15.2
	84.4	3.5	11.8		16.8
81-4-11-4	81.2	5.2	8.0	5.3	7.9
	81.0	5.1	8.4	5.2	8.1
	81.1	4.9	8.7	4.8	8.1
	80.5	5.0	9.1	5.0	8.2
	80.4	4.8	9.4	4.8	8.6
	80.0	4.8	9.9	5.0	8.4
	79.5	4.8	10.2	5.2	8.8

TABLE 13 — SILICON EFFECT ON ELECTRICAL CONDUCTIVITY OF SAND-CAST COPPER-SILICON ALLOYS

Alloy	Composition, per cent			% I.A.C.S.
	Cu	Si	Mn	
95-1-4	95.8	2.8	1.0	6.7
	95.8	3.0	1.1	6.5
	94.7	3.8	1.1	5.9
	94.0	4.6	1.1	5.4
	93.6	5.0	1.0	4.8
	Cu	**Si**	**Zn**	
92-4-4	91.6	3.2	4.6	7.3
	92.2	3.4	4.2	7.5
	91.3	3.9	4.3	6.7
	90.2	4.3	4.6	6.4
	91.0	4.4	4.5	6.1
	Cu	**Si**	**Zn**	
81-4-15	80.9	3.8	15.2	6.8
	81.9	4.0	13.9	6.5
	80.5	4.1	15.2	6.0
	82.1	4.4	13.3	5.7
	82.1	4.6	13.1	5.4
	81.4	4.8	13.7	5.1

copper-silicon-zinc alloys (compare the 92-4-4 curve with the 81-4-15 curve, Fig. 10).

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HEAT TREATMENT OF DUCTILE IRON

By W. D. McMillan

ABSTRACT

The heat treatment of ductile iron castings on a tonage basis is considered. It is the purpose of this paper to cover the three types of treatment set up to process the castings. First, a full ferritizing anneal. Second, a sub-critical draw for machinability retaining the "as cast" tensile properties and third a two temperature normalizing in the interests of machinability for small castings furnished against the "as cast" specifications.

INTRODUCTION

The heat treatment of ductile iron castings on a tonnage basis is considered, rather than on a specific or individual casting basis. The planned as well as expedient measures that have been put into practice during a period of about eighteen months of production are covered.

The foundry property originally produced gray iron castings. The melting equipment consisted of three No. 9½ acid lined cupolas. The molding facilities include three mechanized units, side floors for short runs and four slinger floors.

In February 1957, a 66 in. externally water cooled refractoryless cupola was installed to melt iron of a composition suitable for ductile iron. This is operated with a basic slag in the interests of a low sulfur content. No other major changes in equipment were made at that time. Currently with increase tonnage on schedule, as well as a considerable potential increase, new facilities are being provided.

Two grades of ductile iron are regularly produced:

As-Cast	80-55-06	Brinell 192-241
Annealed	64-45-15	Brinell 156-212

Because ductile iron will show a hardness of 300 Brinell when air quenched from 1650 F, and will also self-anneal in the mold under the right conditions, to show a hardness as low as 166 Brinell, considerable variation in hardness is to be expected. Casting hardness varies with the rate of cooling and the temperature at which they are shaken out.

The process set up to provide a full ferritic structure utilizes existing annealing equipment in the malleable foundry. The furnace is a batch-type unit with a maximum load of 15 tons, although the heats may run as low as 10 tons of castings. It is a radiant tube fired furnace and a high nitrogen atmosphere is used. The castings are not cleaned after annealing. The heat up period will vary depending on the temperature to which the furnace drops between heats. The cycle is basically as follows:

Heat up to	1600 F	8 hr
Hold at	1600 F	3 hr
Cool to	1350 F	3 hr
Hold at	1350 F	3 hr
		14 hr

A complete cycle can be made in about 17 hr including loading and unloading.

The mechanical properties based on results of the Y Block tests show the following:

Hardness	90% between 170 and 187 Brinell. Maximum hardness 196.
Yield Strength	90% between 49,000 psi and 57,000 psi. Values above 58,000 are associated with higher silicon. Yield of 49,000 psi is obtained with 2.40 silicon.
Tensile Strength	90% between 68,000 psi to 75,000 psi. Higher values associated with higher silicon.
Per Cent Elongation	90% between 18 and 22%. 10% between 16 to 18% elongation.

Casting specified annealed fall into two groups.

1) Those requiring higher ductility because of adjustment in assembly and because of service conditions.
2) Small gears that because of the freezing rate of light sections will show carbides are annealed for machinability. These gears are machined and heat treated to a hardness of about 50 Rockwell C.

DUCTILE IRON COMPOSITION

As mentioned earlier, the composition of the ductile iron is such that the castings will air harden when dumped hot.

The manganese ranges from 40 to 50 points, and reflects the manganese content of the steel scrap which establishes the manganese level.

The copper content ranges from 6 to 12 points. This level also is established by the copper residual in the steel scrap.

The nickel content is maintained at 40 points, and results from the use of nickel bearing treatment alloy. The nickel content contributes about 2500 psi to the annealed iron, and constitutes a safeguard against a yield point below the 45,000 psi specified.

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With the high air hardenability and a fast shake out, castings of an intermediate section size and intermediate cooling rate show hardness values higher than 241 Bhn, ranging up to 321 Bhn.

Castings in this group are usually made up of ½-in. to 1 in. sections. Location and size of gates and feeders influence the amount of retained heat which affects the ultimate hardness.

The freezing rate of castings in this group is such that no carbides are present, and the hardness results from the rate of cooling or air quenching rather than from the freezing rate of the metal. The temperature from which the casting is air cooled is the controlling factor. These castings are processed by a sub-critical anneal consisting of 3 hr at 1200 F and air cooled. This practice is an expedient rather than a planned process, and has become necessary on certain castings as a result of the hardness developed by hot dumping. This treatment is carried out in a push-type, open-fired furnace which will handle about 700 to 800 lb per hr. Being open fired, the castings are airless-blast cleaned after annealing. This operation is also performed in the same type of furnace as used for the full anneal, the temperature being held at 1200 F for 3 hr.

This is essentially a ferritizing treatment. At 1200 F, ferritizing is not complete and a hardness level maintained of approximately 200 Bhn. At this hardness, the mechanical properties of tensile, yield and elongation will meet the requirements of the as-cast grade.

The 1200 F temperature has been established for the metal produced in this foundry, and takes into account the character of the iron as influenced by the melting operation, residual elements and the manganese, phosphorus and nickel content.

For metal melted under different conditions and of different composition, a higher or possibly a lower sub-critical temperature would be necessary to maintain a hardness at a given level.

BRINELL HARDNESS

The two specifications produced combined show a total spread of hardness of 156 to 241 Bhn. Actually there is an over lap of 20 points of Brinell hardness 192 to 212, which could apply to either the as-cast or the annealed grade. However, from the standpoint of elongation and formability, and sub-critical anneal does not produce the properties or characteristics obtained by an anneal involving a full austenitizing. It is not a satisfactory alternate treatment if the properties obtained by a full anneal are required. It is satisfactory as a treatment where the anneal is performed only to provide a structure of higher machinability.

A third heat treatment process has been set up. This is for castings specified as-cast, but which because of section size, and consequently, freezing rate, will show some carbides. Light section ¼-in. to 3/16-in. castings fall into this group, and fortunately constitute only about 3 to 5 per cent of the tonnage. Wall thickness is not necessarily the determining factor. "Dead ends," particularly in the drag, are more liable to show carbides than similar sections where the metal can flow through the cavity.

This treatment consists of a two-temperature normalize. It is essentially 2 hr at 1650 F to break up the carbides, cooling to 1450 F and air quenching after 2 hr at this temperature.

Obviously, a sub-critical treatment will be ineffective in removing carbides, and since the specifications require a minimum of 80,000 psi the full annealing treatment cannot be used. This is the reason for the two temperatures normalizing practice.

Castings showing carbides may run as high as 340 Bhn, and as low as 255 Bhn. On heavy section castings, the hardness may be as high as 285 Bhn, and show no carbides. A hardness of 295 or 302 Bhn is regarded as suspicious from the standpoint of carbides. The shape of the casting, size and location in the mold, with respect to the flow of the metal, is better basis for singling out castings that will show carbides than a Brinell hardness test. This is also a lot more practical as many light castings are too small to obtain Brinell readings.

TENSILE PROPERTIES

This heat treatment results in lowering the hardness from the vicinity of 300 Bhn to a range of 217 to 241 Bhn. The tensile properties range from 84,000 to 100,000 psi tensile strength, 63,000 to 68,000 psi yield strength with elongation 10 to 12.5 per cent. These values are generally higher than obtained on as-cast bars at the same hardness levels.

This process is an expedient measure but appears to be of a permanent nature. It relates to a condition that is inherent to the metal composition suitable for ductile iron. However, the 1200 F process is of a less permanent nature, and could be eliminated or at least to great extent by lowering the shake out temperature, which is the dominating factor in causing high as-cast hardness.

The as-cast tensile properties based on Y Blocks, cooled in dry sand molds, reflect the variations in composition, principally silicon and carbon, as the other elements are fairly uniform.

A survey of two representative months production shows that 90 per cent of the results were in the following range:

Tensile Strength	84,000 to 90,000
Yield Strength	56,000 to 67,000
% Elongation in 2 in.	6 to 15 – Ave. 10.9

It is the purpose of this paper to record the three types of heat treatment set up to process ductile iron castings produced at this operation. These represent the measures taken and pertain to this specific operation. They would not necessarily apply without some modification to the product of other foundries.

The economic virtue of ductile iron lies in as-cast ductility. It is referred to as "the cast iron that can be bent," which should be qualified as to how much bend and at what hardness.

There lies ahead further study of composition, character of the charge materials and modification of the facilities in the interest of increasing the tonnage that can be used as-cast.

RADIOGRAPHY, MICROSTRUCTURE AND MECHANICAL PROPERTIES OF CAST MAGNESIUM–THORIUM–ZIRCONIUM ALLOY HK 31A

a correlation

By T. R. Bergstrom and R. G. Bassett

ABSTRACT

Radiographs of cast HK31A magnesium parts exhibit sweeping dark lines, light areas of both circular and angular outline, light areas similar in shape to shrinkage cracks and mottled or banded areas. These indications are excellent evidence of macrosegregation in the castings. An evaluation of the effect of this segregation on the mechanical properties of the cast material was essential to continued use of the cast parts. Several castings were selected on the basis of x-ray indications to be cut into tensile specimens representative of the segregation conditions.

These specimens were tensile tested at room temperature and at 500 F. Autoradiographs, radiographs, micrographs and spectographs were made of the specimens to investigate variations in composition and associated effects. It was determined that the x-ray indications were caused by segregation, and that the segregation had a definite effect on the microstructure. Severe segregation was found to lower mechanical properties. Regions deficient in alloying elements had reduced elevated temperature mechanical properties, but had normal room temperature properties.

Areas of high alloying element content were found to have reduced mechanical properties at both room and elevated temperature. Radiographic standards were established on the basis of the evaluation.

INTRODUCTION

The demand for light alloy castings capable of retaining relatively high strength at elevated temperatures led to the development of magnesium alloys containing the rare earth metals, thorium and zirconium. These alloys have been useful in aircraft and missile design, and their increased use is almost certain. Although there are several commercial casting alloys of this type, the following discussion is based on testing and evaluation of the magnesium alloy designated HK31A (chemical composition: Th 2.5-4 per cent, Zr 0.5-1.0 per cent, Mg remainder).

Thorium, with an atomic weight of 232 and a density of 11.5, is more opaque to x-ray than magnesium, with an atomic weight of 24 and a density of 1.74. Zirconium, with atomic weight of 91 and a density of 6.5, is also more opaque than magnesium (the absorption coefficient of x-rays increases with the atomic number of the absorbing atoms, the number of atoms per unit volume and the x-ray wave length).[1] As a result, portions of a casting that contain higher than normal concentration of thorium or zirconium will absorb greater amounts of radiation and appear as light areas on x-ray films. Conversely, deficient regions will absorb less radiation and appear darker.

These conditions manifest themselves in the radiograph as sweeping dark lines, light circular or angular areas, mottled or banded areas and as light areas similar in shape to shrinkage cracks. They are easily observed and provide excellent indications of gross variations in chemical content. They are also a constant source of perturbation to personnel in the x-ray laboratory.

The determination of the effect of these anomalies on the room and elevated temperature properties of HK31A-T6, and the subsequent adoption of radiographic standards to establish permissible limits, was deemed essential to the use of cast HK31A magnesium as a production material.

INVESTIGATION AND TEST RESULTS

A power-pack door panel casting, as shown in Fig. 1, is used on an interceptor missile. This casting measures approximately 27¼-in. x 20½-in. The configuration has walls as thin as 0.22 in. and one mass roughly 4x1x1½-in. The panel doors are given complete x-ray inspection, and on this basis several were selected for the testing and evaluation reported herein. The selection of specimens from the castings required repeated dissecting and x-ray checks to insure selection of the exact conditions desired.

Unfortunately, many of the best illustrations of the conditions in question occurred where the configuration was such that tensile specimens could not be obtained. The shape and size of the tensile specimen selected can be seen in Figs. 2, 3 and 4. For room temperature testing the specimen thickness was as near the thickness of the casting as possible, but for the elevated temperature testing it was necessary to standardize on two thicknesses (0.220 and 0.160 in.) to permit a uniform heating rate. Altogether, a total of 39 specimens was tested, 25 at room temperature and 14 at 500 F (260 C).

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The elevated temperature testing was performed in a 10,000 lb, radiation-type, quick heat test machine, by bringing the samples to 500 F in less than 30 sec, holding at temperature for 30 sec, and loading to cause failure in 3 to 10 sec, or a rate of 4 to 6 ksi per sec. The room temperature loading rate averaged approximately 6 ksi per sec. The test results, together with the condition observed in the gage area, are presented in Tables 1 and 2. Figures 2 and 3 are negative prints of radiographs of the specimens tested at 500 F.

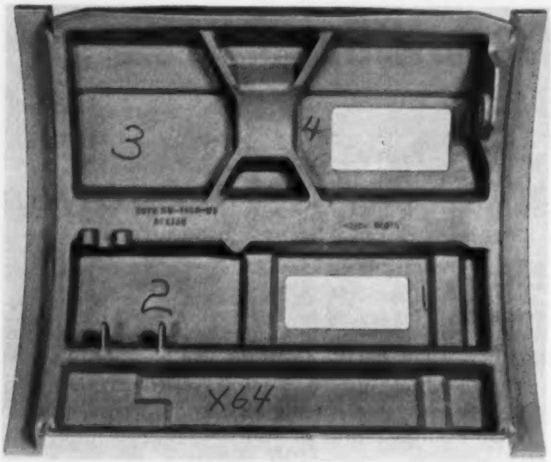

Fig. 1 — Power pack door panel casting.

Figure 4 is a similar print of selected specimens tested at room temperature. Specimens S-3, S-30 (Fig. 2) and F-3 (Fig. 3), respectively, are examples of the spherical type of segregation, the angular type of segregation and the deficiency condition.

It has been possible using radiographic, spectrographic and metallographic examination to determine with fair certainty that a compositional variation is responsible for the effects observed. Thorium, being radioactive, will expose industrial x-ray film in a period of several days. Figure 5 is a positive print of an autoradiograph of specimen S1-4. Figure 6 is a negative print of an x-ray of the same specimen. The fact that segregate particles appear light on the positive print of the autoradiograph indicates a higher thorium content.

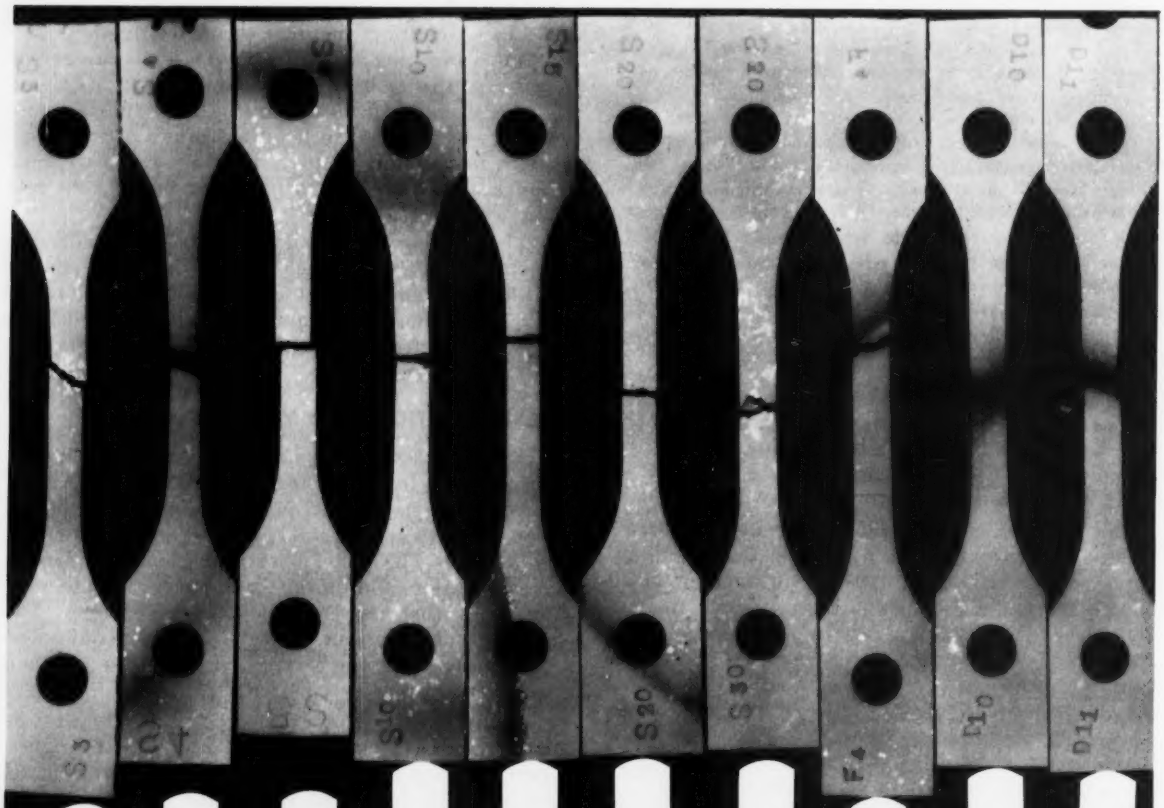

Fig. 2 — Negative print of radiograph showing condition present in elevated temperature samples and location of failure. Reduced slightly in reproduction.

The light appearance of the particles on the negative print of the x-ray indicates that the particles are more opaque to radiation. This would be expected from particles of high thorium content. Similarly, the sweeping dark band evident in Figs. 5 and 6 indicates a low thorium content.

Five of the tensile specimens were examined by emission spectroscopy to compare the chemical composition of the fracture surface with some other area of the specimen. The results of composition analysis by emission spectrographic method are given in Table 3.

The thorium results may vary 0.2 to 0.3 per cent from true values, especially on the fracture surfaces. The zirconium analysis should be accurate to ± 0.05 per cent where near the mean value of 0.6-0.7 per cent. The two high zirconium readings are about twice the value of our highest quantitative standard.

Figure 7 is a photomicrograph of a section of one of the smaller spherical segregate particles evident in the gage area of specimen S-17, Fig. 4. All observed

TABLE 1 — ROOM TEMPERATURE TEST RESULTS

Spec. No.	Condition Present in Gage Area	Ultimate Tensile Str., psi	0.2 Per cent Offset Yield Str., psi	Elong. Per cent in 1 in.	Remarks
CT-1		30,700	16,000	8	Control specimen
CT-2		30,300	14,600	10	Control specimen
CT-3		33,700	16,300	10	Control specimen
CL-1		29,700	20,100	8	Control specimen
CL-2	Clean	33,500	16,600	8	Control specimen
CL-3		31,400	15,500	9	Control specimen
S1-1		30,700	14,600	7	Control specimen
S1-2		29,300	14,700	7	Control specimen
S-32		30,400	16,000	8	Control specimen
	Averages	31,077	16,044	8.3	
S2-3		26,900	15,500	8	Failed in segregated zone.
F-1	Heavy segregation	26,200	14,600	7	Failed in segregated zone.
S-14		26,600	16,500	3	Failed in segregated zone.
S-17		26,300	16,200	3	Failed in segregated zone.
	Averages	26,500	15,700	5.25	
S1-3	Moderate segregation	29,000	14,600	6	Failed in clean zone.
S1-4	Moderate segregation	28,100	15,600	7	Some segregation at break.
S-11	Moderate segregation and deficiency	28,300	14,100	5	Failed in segregated zone.
S2-1	Light segregation	30,600	15,400	8	One segregate particle in break.
S2-2	Light segregation	30,900	14,800	8	Failed in clean zone.
	Averages	29,380	14,900	6.8	
F-2A	Th deficiency	31,000	14,900	10	Failed 1/8-in. from sharp indication.
F-3	Th deficiency and light segregation	29,000	17,300	8	Failed in segregation zone 1.
F-5A	Th deficiency	29,300	14,400	9	Failed 1/4-in. from sharp indication.
F-2	Th deficiency	35,000	14,700	6	Failed 1/2-in. from sharp indication.
F-5	Th deficiency	30,900	14,100	5	Failed 1/4-in. from sharp indication.
F-6	Th deficiency	34,700	16,100	7	Failed in deficient zone.
	Averages	31,650	15,250	7.5	
F-4	Th deficiency and dross	26,600	14,600	6	Failed in dross.

TABLE 2 — 500 F QUICK HEAT TEST RESULTS

Spec. No.	Condition Present in Gage Area	Ultimate Tensile Str., psi	0.2 Per cent Offset Yield Str., psi	Elong. Per cent in 1 in.	Remarks
S-4	Clean	23,700	13,100	18	Control specimen
S-15	Clean	26,000	*	10	Control specimen
**	Clean	22,100	12,114	18.4	
S-3	Heavy segregation	20,800	12,800	10	
S-30	Heavy segregation	16,900	13,400	6	
S-10	Medium segregation	22,300	*	6	See Figs. 2 and 3 for positions of failure.
S-20	Light segregation	23,400	13,300	8	
S-2	Light segregation	21,000	11,800	9	
S-31	Light segregation	19,500	12,700	7	
	Averages	20,650	12,800	7.7	
F-3	Th deficiency	22,600	13,200	20	
F-4	Th deficiency	22,100	12,100	10	See Figs. 2 and 3 for positions of failure.
D-11	Th deficiency	18,800	13,900	16	
D-10	Th deficiency	17,500	9,600	10	
	Averages	20,250	12,200	14	
S-9	Mottled type segregation	22,000	14,400	9	See Fig. 3 for position of failure.
L-1	Light stress segregation	21,800	13,000	9	Specimen failed in bolt hole.

*Curve not suitable to obtain yield strength.
**Average of eight other specimens of HK31A tested similarly.

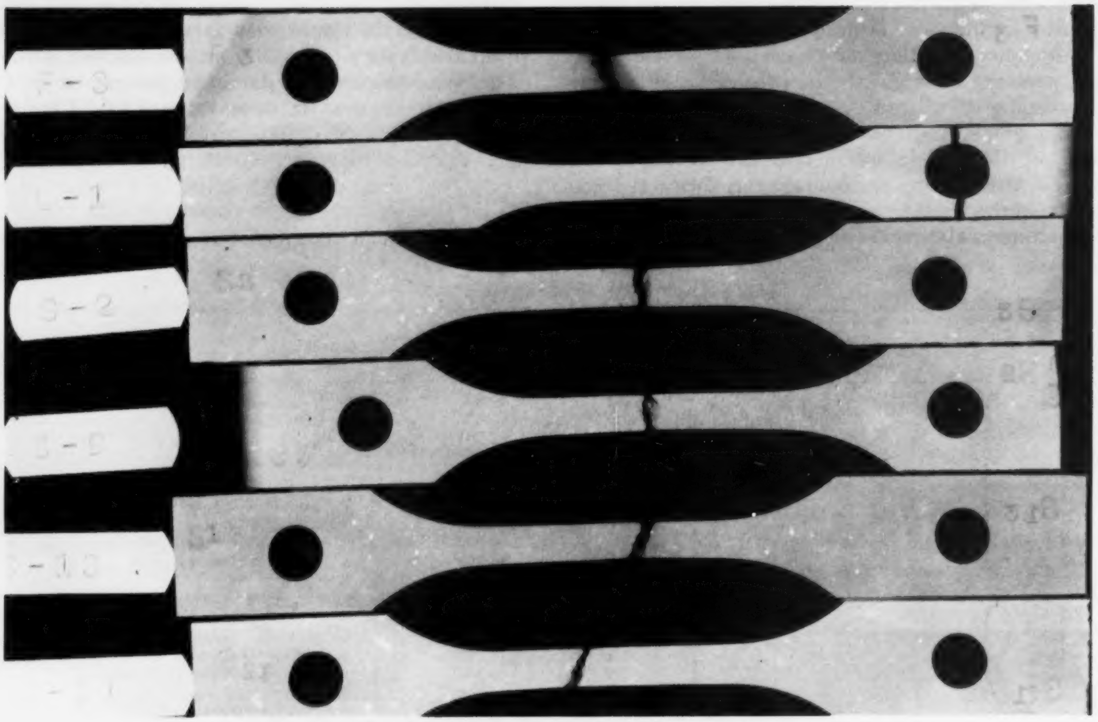

Fig. 3 — Negative print of radiograph showing condition present in elevated temperature samples and location of failure.

TABLE 3 — FRACTURE SURFACE CHEMICAL COMPOSITION

Specimen	Thorium Fracture, %	Thorium Specimen Surface, %	Zirconium Fracture, %	Zirconium Specimen Surface, %
F-3 (Fig. 3)	1.2	3.5	0.43	0.66
D-11 (Fig. 2)	2.0	2.2	0.60	0.67
S-11 (Fig. 4)	1.7	2.4	0.71	0.70
S-30 (Fig. 2)	3.9	2.5	1.25	0.68
S-17 (Fig. 4)	3.1	2.4	1.00	0.65

particles of this type had a clearly defined periphery, and most had a void in the center. Figure 8 at 1000 × was taken of the inside of the particle, and shows a lamellar eutectic-type structure similar to that reported by Yamamoto, Klimek and Rostoker.[2] The ternary system magnesium-thorium-zirconium has been examined with nominal zirconium contents of 0.5, 0.75 and 1.0 per cent, and thorium contents ranging from 0.5 to 6.5 per cent. Reference 2 is the report on this work.

A tentative vertical section diagram at constant 1 per cent zirconium has been constructed. This diagram (Fig. 9) indicates that in solidifying, an alloy with 3 per cent thorium would produce only magnesium solid solution. Subsequent cooling to below about 1000 F (538 C) would start the precipitation of the intermetallic compound Mg_5Th. Diffusion in this alloy is reported to be quite slow due to the size of the thorium atom. It is then probable that as the casting cools below the liquidus curve a considerable deviation from equilibrium exists.

This deviation or undercooling effect will cause the precipitating magnesium solid solution to contain less thorium than indicated. Therefore, the last portion of the liquid will be of such a composition that a third phase, zirconium solid solution, will form. The zirconium solid solution formed is then consumed in a peritectic reaction with the melt, producing magnesium solid solution and the intermetallic compound Mg_5Th.

The liquid remaining below the temperature of the peritectic reaction will then solidify over a temperature range to produce a eutectic-type structure consisting of magnesium solid solution and Mg_5Th. The spherical shape of the particles, observed in Figs. 2, 3 and 4, their void center, and their eutectic-type structure, suggests that they are being formed while the casting is partially molten, possibly where the metal contains gas pockets.

Figures 10 and 11 were taken respectively on the dark and light sides of the band running roughly parallel to the length of sample S-15, Fig. 2. A sharp difference was noticed in the rate of etching of the grain boundaries in the respective areas. Figure 11, taken on the side of high thorium content, has clearly defined fine grains indicating normal precipitation at the grain boundaries. The fine grained structure can be attributed to a normal concentration of zirconium, which is added as a grain refiner.

Figure 10, taken only 0.062 in. (center to center) from Fig. 11, is on the side of the band with lower thorium content. The grain boundaries are not as readily etched, and the grains are considerably coarser, which would tend to confirm the suspected lack of thorium and zirconium.

The x-ray of specimen S-9 (Fig. 3) reveals what

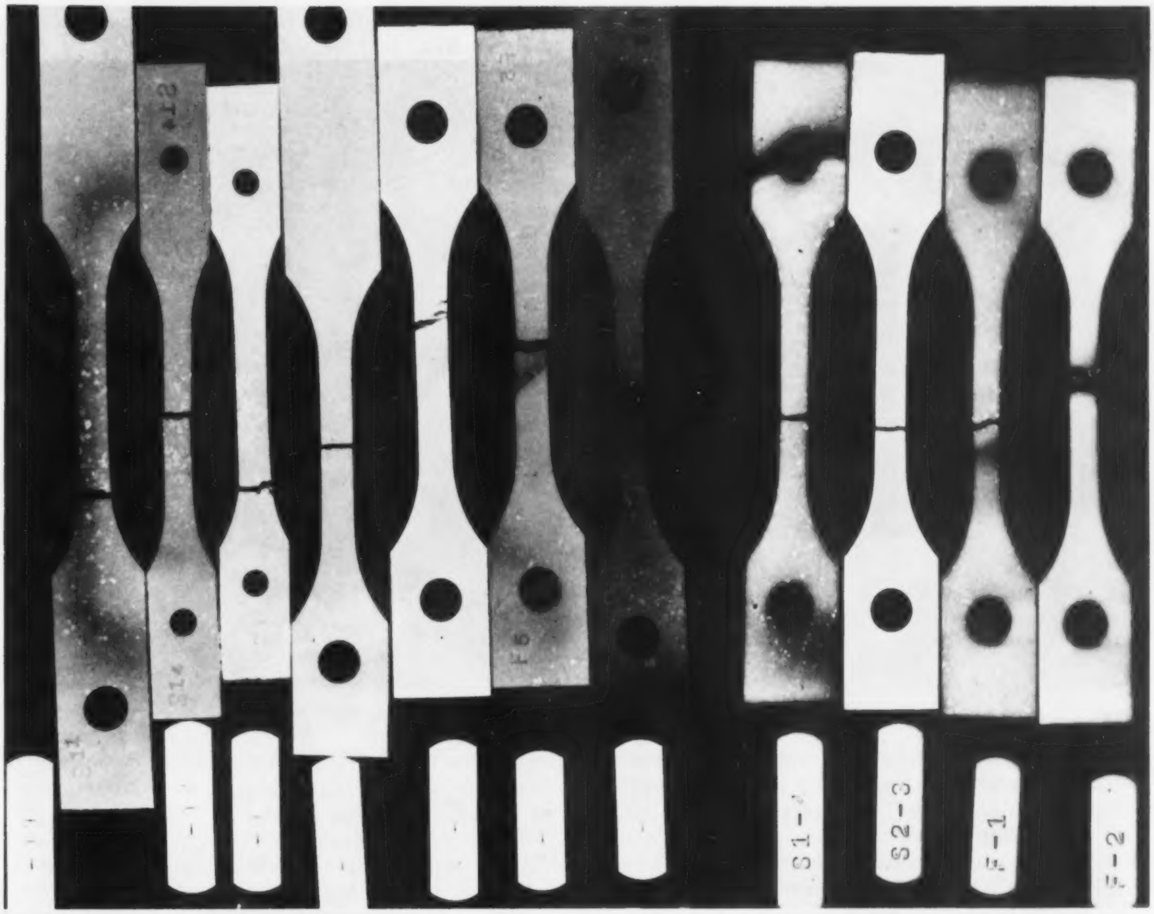

Fig. 4 — (Above) Negative print of radiograph showing condition present in room temperature samples and location of failure. Reduced slightly in reproduction.

Fig. 5 — (Left) Positive print of an autoradiograph of specimen S1-4. 1.7 ×.

Fig. 6 — (Right) Negative print of radiograph of specimen S1-4. 1.7 ×.

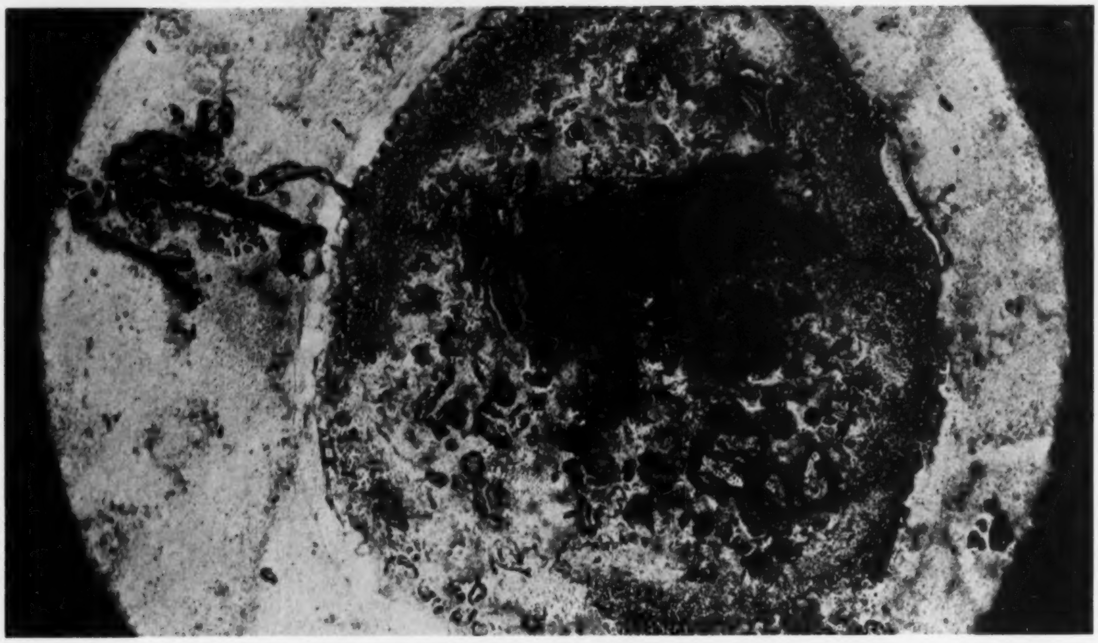

Fig. 7 — Spherical particle observed in specimen S-17. Unetched. 50 ×.

might be termed a mottled or banded appearance. Figure 12 is a photomicrograph of this area, showing grains which contain clusters of precipitated particles. This greater than normal amount of precipitate results in the mottled appearance of the x-ray. Similiar radiographic indications have been observed in EZ 33 castings (chemical composition: rare earth-2.5-4.0, Zn-2.0-3.1, Zr-0.5-1.0, remainder Mg). These indications were associated with microshrinkage being fed by near eutectic material. However, precipitation within the grains was not noted.[3]

Figure 13 is a photomicrograph of one of the angular indications of specimen S-30, Fig. 2. This type defect meanders through the metal in a pattern that might be expected of dross inclusions. The defects are lined with material of eutectic-type structure, although

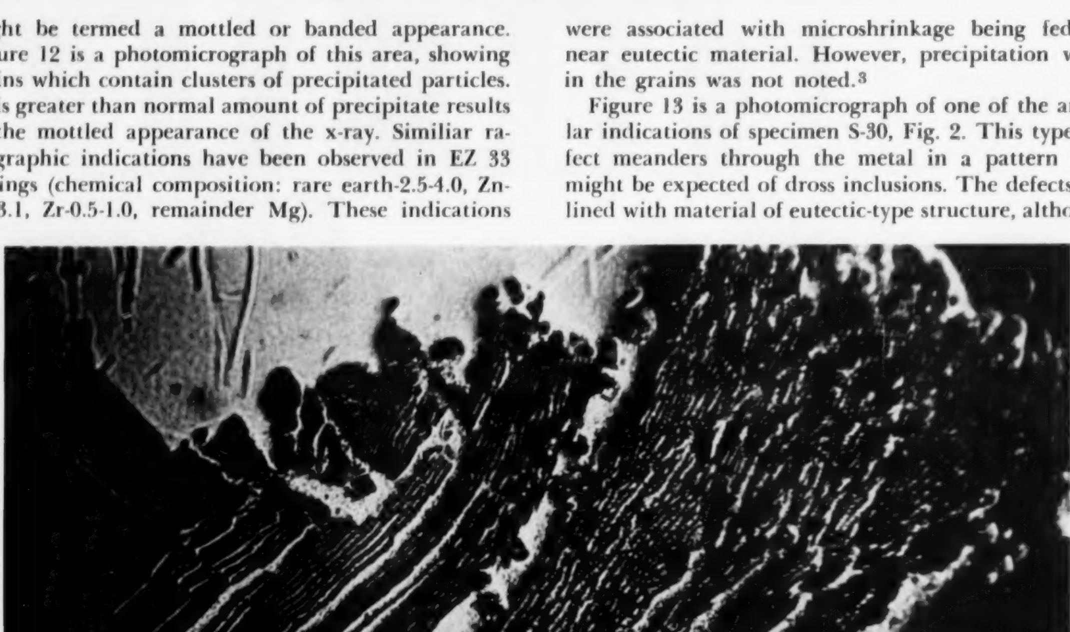

Fig. 8 — Lammellar eutectic-type structure observed in spherical particle shown in Fig. 7. Ethylene glycol 75 ml, distilled water 24 ml, concentrated HNO_3 1 ml, etch. 1000 ×.

the clearly defined lamellar eutectic-type structure of Fig. 8 could not be seen. Figure 14 is a photomicrograph at 1500 diameters of one region of this defect. These defects are similar to the spherical type in that they have a void region in the center.

DISCUSSION AND CONCLUSIONS

An examination of Table 1 indicates that the deficiency condition does not affect the room temperature mechanical properties of the material. It will be noted that the room temperature specimens of Fig. 4 did not fail in regions of deficiency. Conversely, testing at 500 F shows that the deficiency condition definitely promotes failure. This can also be observed from the location of the applicable fractures in Figs. 2 and 3. The values of Table 2 show that this condition reduces average ultimate tensile strength by about 8 per cent, and the per cent elongation by about 24 per cent.

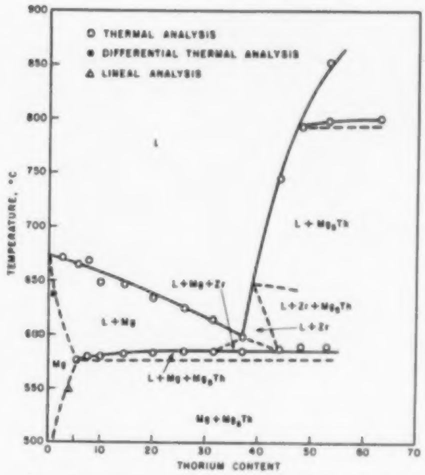

Fig. 9 — Tentative vertical section of the magnesium-thorium-zirconium ternary at 1 per cent Zr. From WADC TR-411, ref. 2.

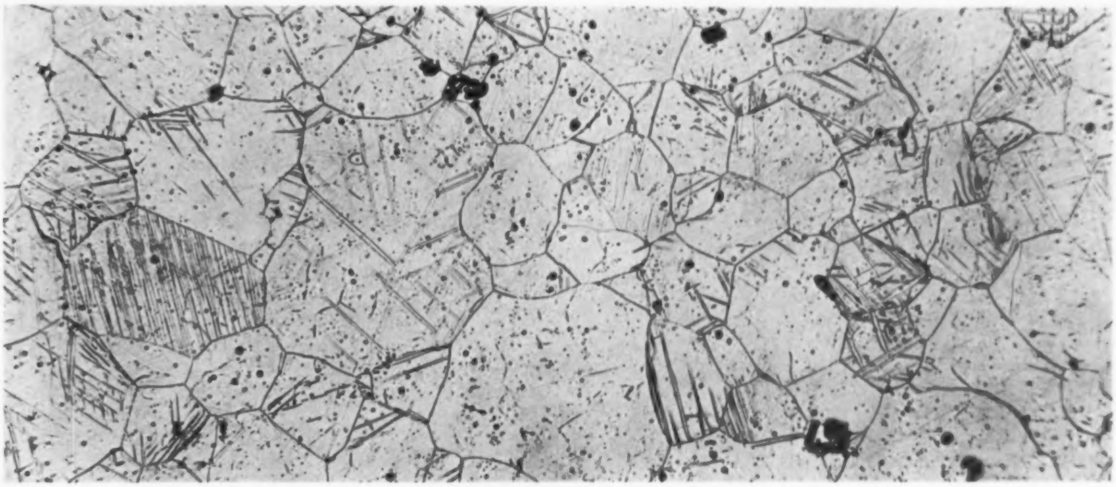

Fig. 10 — Grain size observed on the dark side of the band appearing in specimen S-15, Fig. 2. Ethylene glycol 75 ml, distilled water 24 ml, concentrated HNO_3 1 ml, etch. 100 ×.

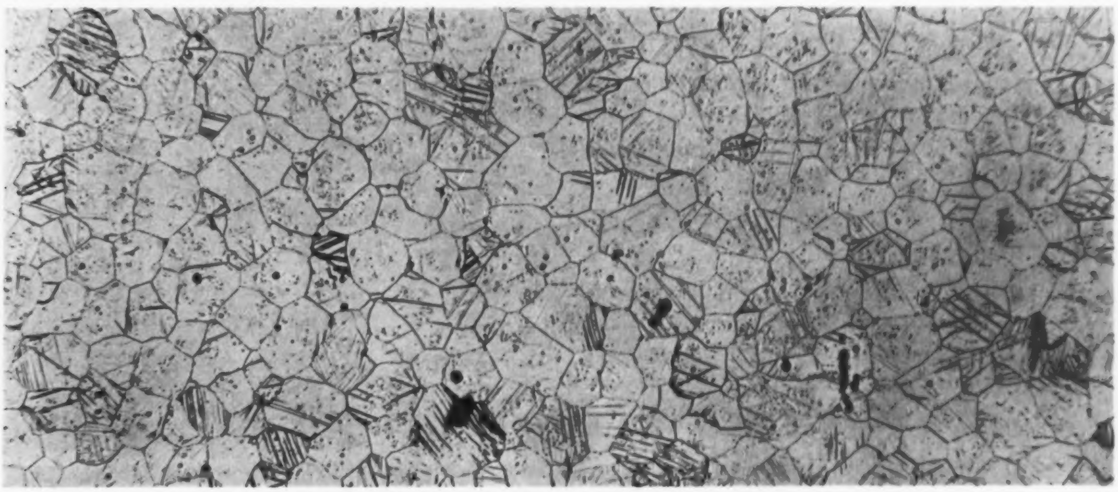

Fig. 11 — Grain size observed 0.062 in. from Fig. 10 (horizontal center line distance), or on the light side of the band of specimen S-15, Fig. 2. Ethylene glycol 75 ml, distilled water 24 ml, concentrated HNO_3 1 ml, etch. 100 ×.

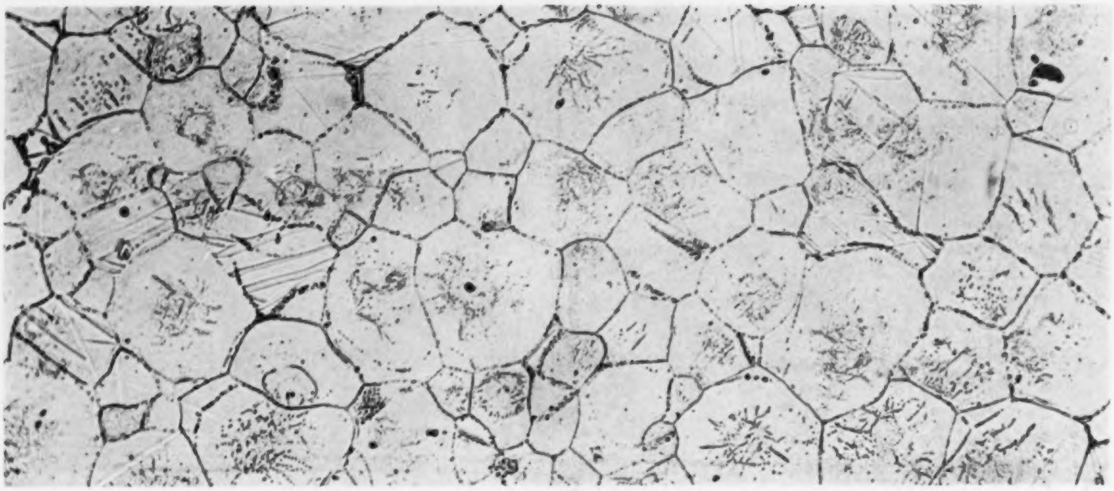

Fig. 12 — Photomicrograph of mottled area of specimen S-9, Fig. 3. Ethylene glycol 75 ml, distilled water 24 ml, concentrated HNO_3 1 ml, etch. 250 ×.

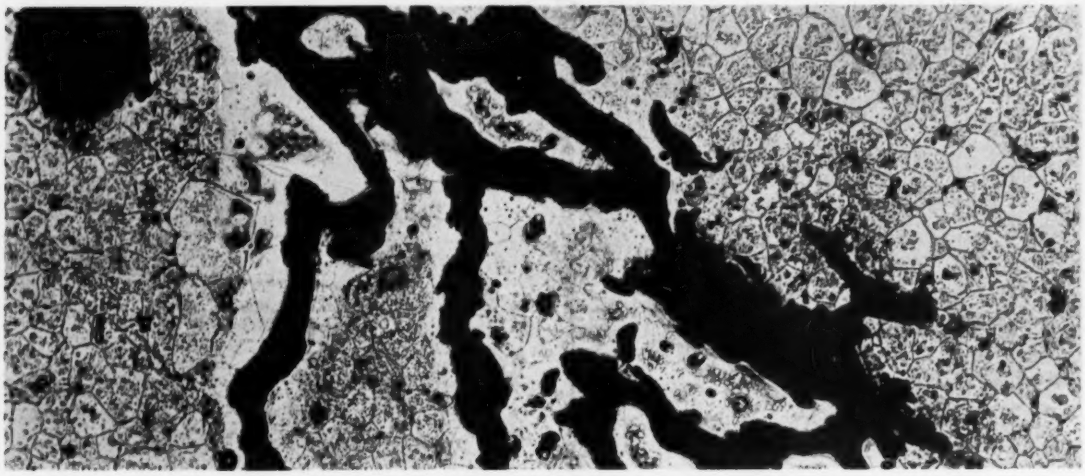

Fig. 13 — Gross imperfection that caused one of the angular indications appearing in specimen S-30, Fig. 2. Ethylene glycol 75 ml, distilled water 24 ml, concentrated HNO_3 1 ml, etch. 75 ×.

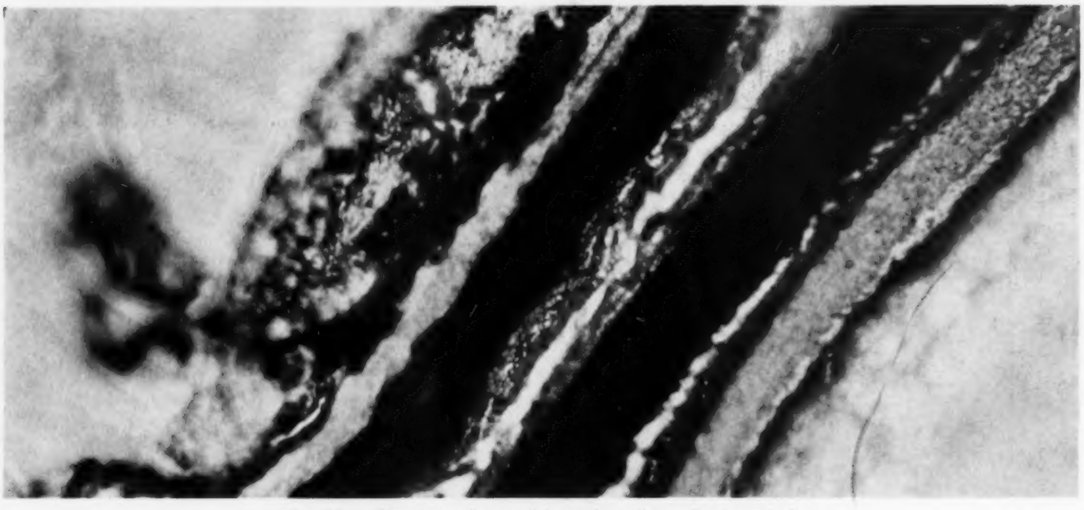

Fig. 14 — Structure observed in region of angular type indication appearing in specimen S-30, Fig. 2. Unetched. 1500 ×.

This reduction would be expected considering that thorium is added to impart high temperature strength. The coarse grain size observed in association with deficient regions is believed to be significant in contributing to the loss of ductility and ultimate strength.

The condition of spherical and angular segregation has the effect of reducing ultimate tensile strength and per cent elongation at both room and elevated temperature. Room temperature testing of specimens with heavy segregation showed an average loss in ultimate tensile strength of 15 per cent, and a loss in per cent elongation of 37 per cent. The average 500 F ultimate tensile strength and per cent elongation values of all specimens with spherical and angular type segregation were found to be 7 and 58 per cent, respectively, lower than observed in the normal samples.

Although only two specimens containing the angular appearing segregation were tested, their performance and the nature of the defect indicates that they are more detrimental than the spherical type. Neither segregation nor deficiency had any significant effect on the 0.2 per cent offset yield strength, or the proportional limit of the material at room or elevated temperature.

All of the specimens tested met the mechanical property requirements of Federal Specification QQ-M-56a for specimens cut from the casting. The authors' company has, however, found it necessary to design castings on the basis of higher mechanical properties. Certain critically stressed regions of the casting, shown in Fig. 1, are required to have the following room temperature mechanical properties: 27,000 psi minimum ultimate tensile strength, 13,000 psi minimum yield strength at 0.2 per cent offset, and 4 per cent minimum elongation.

These regions are expected to have properties of 19,000 psi minimum ultimate tensile strength and 10,700 psi minimum yield strength when tested at 500 F. In order to be relatively certain that these castings will perform to expectation, it was deemed necessary to add an additional inspection requirement to the already thorough inspection procedure.

This requirement is that regions of castings that are delineated as being critically stressed may not exhibit segregation or deficiency in excess of that illustrated in the three x-ray standard film blocks, shown in Fig. 15. Although these standards do not cover all eventualities, they are a step in the right direction, and they will be used by the authors' company until replaced or supplemented.

The trend in casting design for missile applications is becoming exceedingly clear. The extensive use of castings for missile structure application will depend on the casting industry progressing to where it can offer the missile designer the following advantages:

1) Guaranteed strength and ductility in the casting. Separately cast test bar values will not be acceptable.
2) The maximum in consistency and reliability throughout the parts of any lot, and between all lots of any part. Castings to be competitive cannot be penalized by any casting factor. Accurate analysis of heats is an absolute necessity.

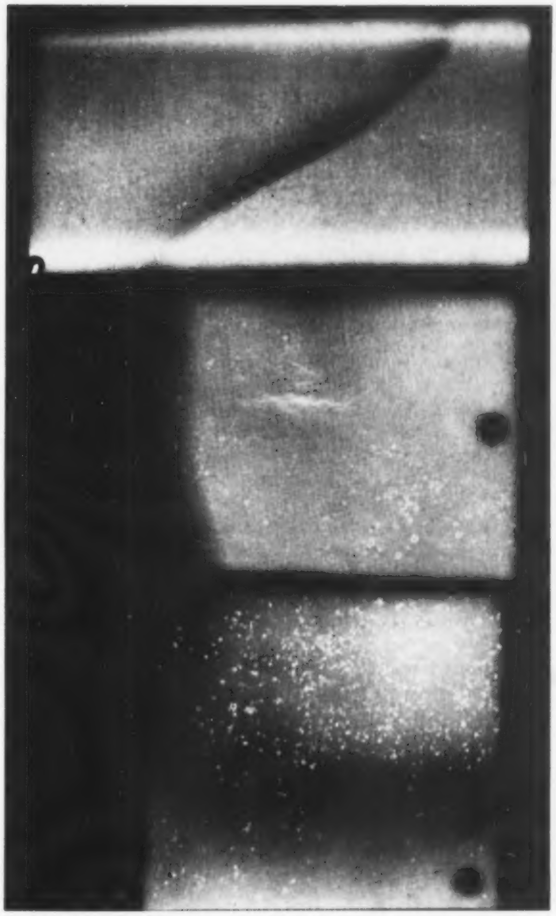

Fig. 15 — Negative print of x-ray standard radiograph for use in critically stressed regions of cast thorium magnesium.

3) Strength and ductility equal to that obtained in wrought products. Castings will have to be designed on the basis of the ultimate in wrought properties.
4) Increased dimensional accuracy permitting the maximum use of as-cast surfaces.
5) Specifically formulated casting alloys to compete with the wrought superalloys.

The airframe industry is usually limited to investigations of the type represented by this discussion. The foundry, because of its nature, must perform the basic research and development needed to eliminate the various causes of defects, and provide the missile industry with sound, strong, reliable castings.

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GRAY IRON PERMANENT MOLDING

By H. U. McClelland

ABSTRACT

Although the tonnage of gray iron castings produced in metal molds is relatively small when compared to the tonnage produced by all casting methods, it is felt by the author's company and others producing quality castings by this method that their contribution to the users of castings is important.

The purpose of this paper is to present a short history of the origin and development of gray iron permanent molding, a description of the process and the methods used in the design and fabrication of the molds. The metallurgy and dimensional tolerances of the castings produced by the process will be discussed as well as the scope of the process and its advantages and disadvantages. It is hoped that the paper will give the producers of castings by other methods a better understanding of the procedures used, and that the users of gray iron castings will be given a picture that may help in their purchasing decisions for product applications that can be served by this process.

INTRODUCTION

Although the use of permanent molds in the casting of metals is centuries old, the first successful method for molding gray iron castings in production quantities is that which will be discussed here. The process is approximately 35 years old, having been conceived and developed by a manufacturer of automotive carburetors who was having difficulty procuring gray iron castings, free of porosity, and who, though having no foundry experience or facility, decided to enter this entirely new field. As in most ventures of this nature, there were many disappointments and failures, and several times during the early development the project was almost abandoned.

The key to ultimate success was the formulation of an adequate mold coating which permitted molten metal to be poured into metal molds of similar analysis without fusing. The facility was operated as a captive foundry for several years, casting carburetor components exclusively and manufacturing permanent mold machines for sale. The decision was then made to enter the commercial casting field and discontinue the sale of machines domestically. In 1932, the author's company acquired ownership of plant and patents, and has continued to expand and develop the process. Several installations are in operation under license in the United Kingdom and continental European countries.

In the United States, at the present time, there are three other foundries producing gray iron castings by this method and in the size range of those produced by the author's company; two are captive, one commercial.

The method to be described is unique and different from other means of producing gray iron castings only in respect to the molding material used, the manner in which the molds are conveyed, the products used in the manufacture of the molds and the preparation of the molds for pouring. After the mold is poured and the casting removed, subsequent operations required to prepare the part for shipment and ultimate use are similar to those inherent to all foundries.

Mold Transport Technique

Present day production foundries, with few exceptions, use various handling devices and techniques to transport molds through the making and pouring cycle. In the permanent mold process, the conveyor used is a turntable type of machine which carries the mold through the following cycle:

1) Mold preparation where a thin coating of carbon is deposited on face.
2) Core setting (if cores are required).
3) Pouring.
4) Ejection or shake-out of the casting.

This machine, approximately 14 ft in diameter, consists of a hub from which project 12 hollow arms to which are attached the outer or stationary heads used to support one-half of the mold. The inner or movable heads are actuated by air cylinders whose movement is controlled by cam-operated valves. Both heads have air passages through which approximately 500 cfm is drawn across the back of each half mold for the purpose of cooling. This air passes from the heads, through the hollow radial arms to an exhaust stack. The speed of rotation is controlled by an infinitely variable speed reducer which guarantees a constant cycle speed, determined by the solidification rate of the castings being produced.

All operations are performed while the machine is in motion. It is extremely important that the continuity of operation be maintained at all times with a minimum of interruptions for any reason. Quality and uniformity of product depend greatly on this continuity. The advantages gained, volume-wise, are quite obvious. Shut downs of short duration for mold

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cleaning or alignment and minor mold repairs are necessary and permissible, but are rigidly controlled.

The metal mold consists of two shallow open boxes, the closed sides containing the casting cavities and the gating system, the narrow sides forming air chambers in which are integrally cast cooling pins and/or fins to assist in the dissipation of heat from the mold. The metal used to cast these mold halves has essentially the same analysis as that of the castings produced by them, which means that worn-out molds can be remelted as regular returns. Other metals and ferrous alloys have been tried, but this is the analysis that the author's company has found to give the longest life and best operating conditions. Castings for the mold halves are cast by conventional means, either in oil sand or green sand.

The CO_2 process has also been used in making certain types of mold castings, and has been found to have definite advantages. When the contour of the casting to be produced is complicated, and it is difficult and costly to form the mold cavities by machining, it has been found economically sound to purchase mold castings from a producer of precision castings. A minimum of machining is then necessary, and any number of exact duplicates can be made. These molds will be as dimensionally accurate as the pattern from which they are made.

Mold and Casting Drawings

Before the mold is designed and fabricated, a casting drawing of the part to be produced is submitted to the customer for approval of any minor changes which are considered desirable from a foundry standpoint, and which will not be detrimental to processing or ultimate function of the casting. It is often possible to recommend design changes which reduce weight, increase strength or eliminate processing operations, thereby reducing costs and assisting the customer in the engineering of his casting. Complete mold drawings are made after receipt of customer approval of the casting drawing. Since all molds are standard in size, with a maximum face area of 16x20 in., placement of cavities to secure the maximum potential is most important.

Ordinarily center sprues are used, but where size or weight does not allow multiple cavities offset sprues are employed. Various gating systems are used, the determination of the type employed is largely dependent on past practice, type and size of casting and placement of cavities. In multiple-cavity molds the risers of the lower cavities serve as gates of those above. The standard gate is 0.065 in. deep with the width variable, but in certain applications gates as small as 0.025 in. in depth have been successful. The gate size, the size and shape of sprue and runners are important in the elimination of slag and impurities in the casting cavities and the control of pouring time.

As in all casting processes, pouring time is one of the most important elements in the casting process, and in permanent molding this function of the gating system is most significant. Inasmuch as a metal mold has no permeability, and in this process all molds are poured in a vertical position, time must be allowed to exhaust the air contained in the cavities through the risers which act as vents. Where gases or air is entrapped means must be provided for removal. This is accomplished by the insertion, where necessary, of small round plugs from which segments 0.015 in. deep have been removed.

This size opening allows air or gas to escape, but restricts the entrance of metal. Since the unique properties of the castings produced by this process are dependent on rapid solidification, anything that can be done to expedite quick freezing is desirable. To achieve optimum results, special consideration is given to the metal thickness and contour of the model backing, the placement of cooling pins and fins to assist in the rapid dissipation of heat from the mold during its cycle. The thickness of the mold backing varies between 0.50 in. and 1.25 in. depending on the shape, size and mass of the casting to be produced.

Core Prints

Where the use of cores is necessary, core prints must be designed not only for accurate location but for suspension in the vertical mold prior to closing. Both oil sand and shell cores are used, the choice depending on economics, the requirements of the casting in dimensional accuracy, complexity of the cavity to be formed in the casting and availability of equipment. In many instances, although the initial cost of shell cores may be greater than that of cores made from oil sand, it has been found that net cost reductions either in the casting itself, or in the ultimate part made from the casting, can be realized.

In other cases, complexity or fragility is such that it is impossible to produce the core by any other method. Considerable savings are also possible in the maintenance and repair of core boxes. Shell cores, being hollow, also expedite the removal of core gases and assist in a more rapid solidification of the metal in the cored areas, especially desirable in this process.

At the author's company, iron of but one type is produced with an analysis of T.C.–3.45-3.65; Si–2.45-2.65; Mn–0.70-0.90; S–0.10 max.; P–0.25 max. This is the analysis that produces castings with the desired physical properties of strength, hardness and machineability with the lowest scrap and highest yield. Since all castings produced by this process are annealed to eliminate all chilled area induced by casting in a metal mold, the resulting microstructure consists of ferrite and finely dispersed eutectiform graphite, with faint traces of pearlite sometimes present. This metal is sensitive to section size, although not to the degree found in other casting methods, and so may contain some fine flake graphite in heavy sections.

The Bhn range is 170-207 and tensile strength 30,000 psi and up, depending on section size. The material is amenable to hardening, either by the induction heating method or the more conventional oil or water quench and draw process. Hardness of R_c 50-55 can be readily obtained with tensile strengths in excess of 50,000 psi.

Tolerances and machining finishes in any casting are always of great interest and importance, and in

these days of automated machining and intense programs of cost reduction, these two characteristics assume even greater significance. Although each casting must be considered individually, the usual tolerance maintained on exterior dimension is ±0.025 in. This degree of tolerance is necessary on dimensions across the parting line due to some mold spread which occurs during the solidification process. However, on small castings of comparatively thin section, tolerances of ±0.015 can be guaranteed.

Locating points and chucking surfaces can be maintained consistently uniform from casting to casting as rigid mold walls produce constant dimension repetitively. Insofar as finish allowances are concerned, customers require different allowances ranging from zero finish to a maximum of 0.090 in., depending on size, warping tendencies of the casting, method of machining and, of course, ultimate use of the casting. It is safe to say that the average finish allowance is 0.060 in. to 0.070 in., with grinding finishes as low as 0.025 in. possible on small flat parts such as refrigeration valve plates.

Maximum Face Dimensions

Inasmuch as the standard production mold has maximum face dimensions of 20x16 in., it is obvious that the size of casting that can be produced is limited to that which can be contained in this face area. Casting weights range from a few ounces to 25 lb, the latter being exceeded when contour or section thickness of the casting permit practical use of the process. Section sizes range from a minimum of 0.190 in. to a maximum of 2 in. Straight parting lines are desirable from a mold cast standpoint, but are not absolutely necessary.

Small radii tend to decrease mold life while decreasing casting strength by abrupt section change. Castings should have a minimum of three degrees draft and, wherever possible, small pockets or deep cavities should be eliminated to increase mold life and maintain uniformity of casting contours.

All casting processes have disadvantages as well as advantages, but the users of the method being discussed feel that the latter definitely outweigh the former. Obviously the greatest disadvantage is the size limitation imposed by mold dimensions. Equipment to increase the scope of the process is being developed at the present time. Since one type of metal is normally used, it follows that certain castings cannot be produced due to analysis and physical property specifications.

Casting Users

Other castings whose complexity of contour or production volume do not permit practical mold life or the initial mold cost are also eliminated. However, there is a large field whose requirements can be more than adequately met by the process. Permanent molding has been proved especially advantageous to those users of relatively small castings, who demand a dense tight metal without porosity which is easily machined. These users include the automotive industry as well as refrigeration, air conditioning, washing machines, miscellaneous appliances, vee-belt sheaves and hydraulic applications.

These users require uniformity of dimension, tolerances and quality as well as a competitive cost. Their acceptance, and continued use of castings made by the process, speaks eloquently of the scope and advantages of the process. Today, the author's company is producing 1200 different permanent mold castings in gray iron for more than 100 customers.

Let it be said in summation, that the producers of castings by the permanent mold process are proud of their past achievements, and look forward to the future with confidence that they will continue to supply quality castings at a competitive price to casting users everywhere.

GREEN TENSILE AND SHEAR STRENGTHS OF MOLDING SANDS

By R. W. Heine, E. H. King and J. S. Schumacher

ABSTRACT

When a pattern is drawn or a mold is handled, shear and tensile forces are exerted on the molding sand. Compressive forces may be applied to the sand by mold weights, closing over onto cores, the weight of the casting itself and, of course, by squeezing in molding. However, if the mold cracks during pattern drawing, molding or handling, it is commonly due to failure of the sand in tension or shear.

Knowledge of the tensile and shear strengths of molding sands, and principles controlling these properties, is therefore necessary to the best utilization of green sand. The principles relating to tensile and shear properties, their relation to other green sand properties and their connection with molding problems are discussed.

MOISTURE PER CENT EFFECT

The moisture content of a particular green sand mixture largely controls its green shear and tensile strengths. To illustrate, consider the data in Table 1. The sand mixture reported in Table 1 is composed of 8.0 per cent southern bentonite and 92 per cent sand (85 AFS). Sand batches weighing 4500 grams were mixed 10 min in a vertical wheel muller to produce the data listed in Table 1, and plotted in Fig. 1. Tensile tests were performed with a green tensile testing machine modified to extend its range to higher strength levels. Figure 1 shows that green tensile and shear strengths decrease as moisture content increases.

Decreasing tensile and shear strength occurs beyond that moisture content which is required for coating the sand grains and clay.[1] If the moisture content is much below that required for coating the sand and clay, the tensile and shear properties decrease and are erratic, and the sand is too dry and brittle for molding. Moisture contents beyond the highest given in Table 1, 4.4 per cent, were considered too wet for molding this mixture and were therefore not studied.

According to principles of mechanics, green tensile and green shear strengths should be related to each other. Thus, the data in Table 1 and Fig. 1 may be replotted, as in Fig. 2, to show this relationship. Figure 2 shows that throughout the range of usable moisture contents, the two properties are related, both decreasing with increasing moisture content. Thus, it might be inferred that testing for green shear strength of a molding sand will adequately reflect the tensile strength (and moisture content) of the sand. However, later it will be shown that other

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TABLE 1 — EFFECT OF MOISTURE ON GREEN SHEAR AND TENSILE STRENGTH*

Mixture	Moisture, %	Tensile Spec. Wt., gm.	Green Tensile Str., psi	Green Shear Str., psi
1. 8% S. bent.	2.7	154	3.8	5.1
92% sand,	3.2	149.5	3.5	6.3
85 AFS	3.6	148	3.1	5.5
	3.8	148	2.8	5.2
	4.3	150.5	2.5	4.5
2. 8% S. bent.	2.6	156	3.1	5.2
92% sand,	3.0	150.5	3.8	6.5
85 AFS	3.4	149	3.1	5.6
	4.0	148.5	2.5	4.9
	4.4	151	2.4	4.5

*Standard AFS specimen.

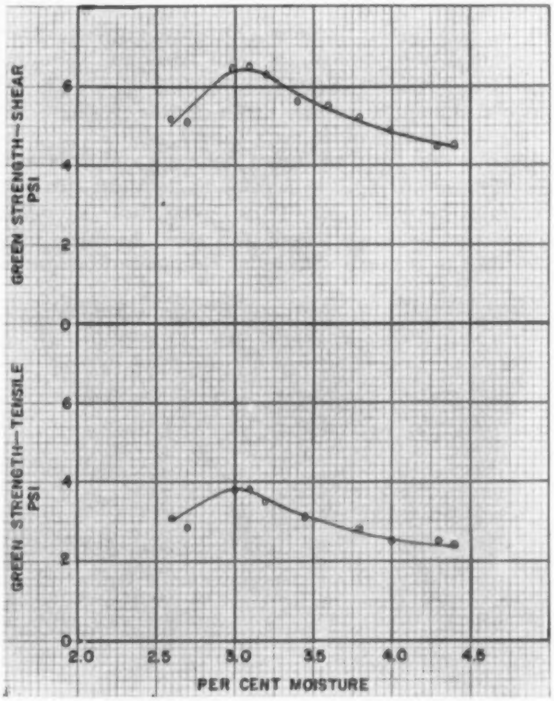

Fig. 1 — Moisture content effect on green tensile and shear strength of a sand bonded with 8.0 per cent southern bentonite. Data of Table 1.

factors can prevent this simple relation from being true.

Other sand mixtures show a relationship of green tensile and shear strength to moisture content similar to that in Figs. 1 and 2 for a specific southern bentonite sand mixture. Thus, the effect of moisture is to control the shear strength of the plastic mixture of clay and water in the aggregate which, in turn, largely determines the other green properties such as tensile and compressive strengths and mold hardness.

RAMMING EFFECT

The ramming effect on green tensile and shear strength was studied for mixtures of various clay contents and clay types. Variation in ramming was achieved through the use of AFS rammers equipped with two different ramming weights, 14 lb and 2 lb, dropped a distance of 2.0 in. Density of the 2.0 in. x 2.0 in. diameter specimen was varied from a lower to a higher value by varying the specimen weight and number of rams with each weight. Table 2 reports the green properties of mixtures of 8 per cent western bentonite, 92 per cent sand mixtures at 3.3 to 3.8 per cent H_2O, mixtures 3-8. Table 2 also lists 8 per cent western bentonite mixtures containing cellulose additives, mixtures 9 and 10. Three different western bentonites were used in the mixtures, as listed in Table 2.

The relationships of the properties are shown in Figs. 3 and 4. Figure 3 reveals that both green tensile and green compressive strengths are proportional to green shear strength up to a value of about 6 psi green shear strength. Figure 4 shows that green compressive strength and bulk density are related to average mold hardness. Obviously green shear strength is also related to mold hardness, although this has not been plotted. Referring to Fig. 3, increased ramming causes green tensile strength to reach a maximum of between 3 and 4 psi.

Above this level, increased ramming causes erratic green tensile strength to develop as the shear strength increases beyond 6 psi. Thus, green shear strength, green compression strength and mold hardness may continue to increase with more ramming after tensile strength reaches a maximum of about 3 to 4 psi in the 8 per cent western bentonite mixtures.

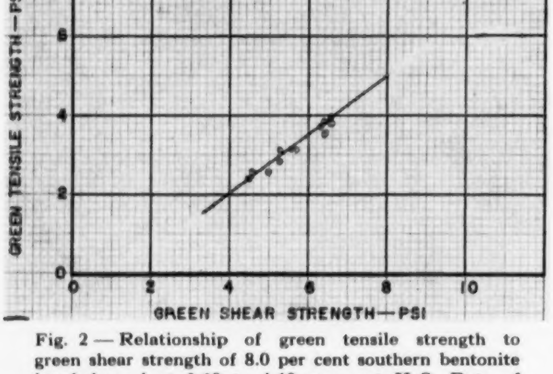

Fig. 2 — Relationship of green tensile strength to green shear strength of 8.0 per cent southern bentonite bonded sand at 2.60 to 4.40 per cent H_2O. Data of Table 1.

The reason for the erratic values of both green tensile and green compression strengths above 6 psi green shear strength in the 8 per cent western bentonite mixture is associated with the density achieved during ramming. Below 6 psi shear strength, increasing ramming to 3 standard rams is accompanied by shear strength of the clay-water bond, the expression of voids, compaction of the sand and greater effective contact area of the clay-water bond within the specimen. Above 6 psi green shear strength (or 154 gram weight and 3 standard rams in this case), fitting together of sand particles and particle to particle contact occurs.

TABLE 2 — GREEN PROPERTIES OF 8% WESTERN BENTONITE MIXTURES

Mixture and Symbol	Spec. Wt. grams	No. Rams*	Green Strength, psi Comp.	Tens.	Shear	Mold Hardness**
3-o 8% W. bent.	148	2	15	2.65	4.6	88
92%-85AFS	154	3	18.6	3.50	5.9	90
sand,	161	7	32.5	4.3	6.8	94
3.3% H_2O	164	10	36.5	4.3	8.0	94.5
	167	12	41.0	4.1	9.1	95.5
4-● 8% W. bent.,	142.5	27*	11.1	1.9	3.6	83
92%-85AFS	147.5	45*	15.9	2.65	4.7	87.5
sand,	153.5	3	16.4	2.80	5.0	89.0
3.8% H_2O	160.5	8	30.0	3.50	7.1	93.5
	164.5	11	32.0	3.70	7.2	94.5
	167.5	14	35.0	3.60	8.2	95.0
5-△ 8% low gel						
(21 sec)	138	18*	8.8	1.7	3.1	80
W. bent.,	148	2	12.2	2.3	4.0	86
92.0%-85AFS	154	3	16.5	2.5	4.7	89
sand,	162	7	27	3.5	6.5	93.5
3.5% H_2O	167	11	32.5	3.7	7.1	94.5
	170	15	35.8	3.7	8.1	95.0
6-▲ 8% high gel						
(30 sec)	138	18*	9.5	1.7	3.20	81.5
W. bent.,	148	2	14.1	2.5	4.4	87.5
92.0%-85AFS	154	3	18	3.0	5.10	89.5
sand,	162	7	28.8	3.8	6.8	94
3.5% H_2O	167	11	35.5	3.8	7.6	94.5
	170	15	40.5	3.7	8.1	95.5
7-□ 8.0% W. bent.	142	15*	8.6	1.7	3.0	82.5
92%-49AFS						
Wedron	151.5	2	14.0	2.3	4.2	88
silica sand	156.5	3	18.4	2.8	5.2	90.5
3.40% H_2O	164.5	7	25.5	3.3	7.1	94.0
	168.5	12	30.5	3.2	7.0	94.5
8-■ 8% W. bent.	139	22*	10.5	1.95	3.6	81.5
92%-91AFS						
Portage	147.5	2	12.7	2.2	4.2	86.5
silica sand	153	3	15.1	2.55	4.6	88
3.40% H_2O	161	8	24.5	3.0	6.7	93
	166	15	32	3.1	7.2	95
9-× 8% W. bent.	139	22*	13.8	2.4	4.6	86.5
91%-85AFS sand	147	2	18	3.1	5.3	90
1.0%-carbonized						
cellulose	153	3	24	3.65	6.5	92
3.40% H_2O	161	8	41.5	5.55	8.5	95.5
	165	10	46.5	4.9	10	96
10-+ 8% W. bent.	141	21*	10.5	1.8	3.3	81.5
91%-85AFS sand	147	2	13.7	2.5	4.8	87
1.0% wood flour	153	3	19.0	3.1	5.3	90
3.9% H_2O	161	6	29	3.8	7.3	93
	168	13	39	3.7	7.7	95

*No. rams marked with asterisk refer to 2.0 lb-2.0 in. rams, others refer to standard 14 lb-2.0 in. ram.
**Ave. of 6 readings, 3 top and 3 bottom.

Particle packing with increased ramming is accompanied by a rise in green compressive strength, but no rise in green tensile strength at the 8 per cent clay level in these mixtures. The rise in green compressive strength is due to particle friction on shear planes. The lack of further rise in green tensile strength is due to the fact that maximum contact area of clay-water bond has occurred when the 6 psi shear strength value is reached, and further ramming or density increase is unable to develop more contact area. The ability to develop more contact area for shear strength hinges on the clay content of the sand.

With less clay, the shear strength for maximum tensile strength will be lower, and with higher clay contents a higher shear strength and tensile strength will be reached. This principle is demonstrated in 10 to 12 per cent western bentonite and 6 per cent western bentonite mixtures listed in Tables 3 and 4, respectively.

The data for 10 and 12 per cent western bentonite mixtures are shown in Figs. 5 and 6. Figures 5 and 6 show that green tensile strength increases uniformly as the shear strength increases due to ramming to higher bulk densities and mold hardness. At the 10 to 12 per cent western bentonite level, tensile strength does not level off at a fixed value as in the case of the 8 per cent western bentonite, even when rammed to average mold hardness of 95. The higher clay content mixtures are regarded as clay-saturated sands, i.e., sands in which the addition of more clay does not produce a further increase in strength at a given hardness. This concept has been defined and demonstrated.[2]

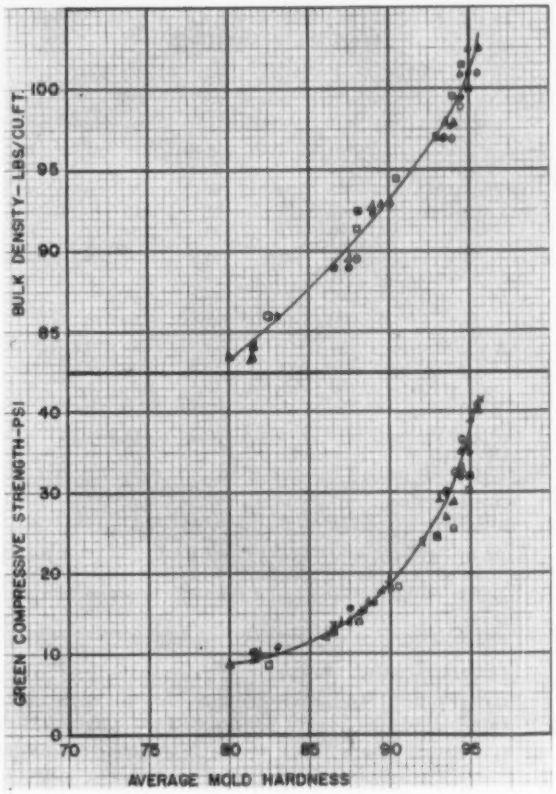

Fig. 4 — Relationship of green compressive strength and bulk density to mold hardness of sands, listed in Table 2 and Fig. 3.

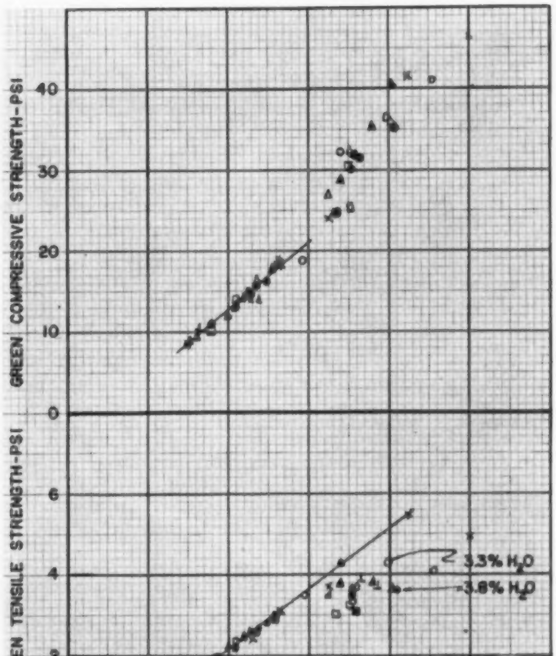

Fig. 3 — Relationship of green tensile and compressive strength to green shear strength in a sand bonded with 8 per cent western bentonite. Data of Table 2.

TABLE 3 — GREEN PROPERTIES OF 10 AND 12% WESTERN BENTONITE MIXTURES

Mixture and Symbol	Spec. Wt., grams	No. Rams*	Green Strength, psi Comp.	Tens.	Shear	Mold Hardness**
12-o	141.5	23	10.7	2.0	4.2	82
12% W. bent.	149.5	2	14.4	2.4	5.1	86
88%-68AFS Silicon	155.5	3	18.5	2.9	6.2	88
sand	163.6	6	30	4.2	8.7	92
4.8% H_2O	168	8	33.5	4.8	9.9	93.5
	172	12	39	5.4	10.2	95
13-●	131	13*	8.6	N.G.	3.2	78
12% W. bent.	135	20*	11.5	2.0	4.0	83
88%-85AFS	139	27*	14.1	2.4	4.9	85
sand	147	2	18.0	2.8	6.0	88
4.5% H_2O	153	3	22.5	3.4	7.2	90
	161	5	31.5	5.2	10.1	93
	165	7	40.5	5.8	11.0	94
14-▲	140	28*	13.0	2.2	4.5	83.5
10% W. bent.	147	2	15.1	2.4	5.3	86
90%-85AFS sand	153	3	19.5	3.1	6.4	89
4.1% H_2O	162	7	34	4.8	9.4	93.5
	164	9	38.5	5.0	9.7	94.5
	170	11	5.3	5.3	10.7	N.D.

*Rams marked with asterisk refers to number of rams with a 2.0 lb weight dropped 2.0 in.; Other refer to standard 14-lb ram.

**Ave. of 3 readings on top and 3 readings on bottom.

TABLE 4 — GREEN PROPERTIES OF 6% WESTERN BENTONITE MIXTURES

Mixture and Symbol	Spec. Wt., grams	No. Rams*	Green Strength, psi Comp.	Tens.	Shear	Mold Hardness**
15-×	148	2	16.5	2.8	4.7	87.5
6.0% W. bent.	154	3	18.4	2.8	6.0	91
94.0% 85AFS sand	165	11	36	2.9	9.5	95
2.60% H_2O	167	15	38	2.65	10.5	95.5
	170	19	41	2.35	11.5	95.5
16-o 6.0% W. bent.	145	28*	11.8	2.65	3.5	85.5
94.0% 85AFS sand	155	3	13.8	2.3	4.1	89
2.90% H_2O	165	12	26.6	2.6	7.3	95
	160	14	28.6	2.6	8.7	95
17-● 6.0% W. bent.	156	3	11.5	1.85	3.2	86.5
94.0% 85AFS sand	161	6	15.4	2.2	4.0	90.5
3.50% H_2O	166	9	17.3	2.3	4.6	92
18-△ 6.0% W. bent.						
94.0% 85AFS sand	157	3	11.0	1.85	3.1	86.5
3.8% H_2O						
19-▲ 6.0% W. bent.	157.5	3	9.5	1.65	2.9	85.5
94.0% 85AFS sand	167.5	10	15.2	2.1	3.5	91
4.1% H_2O	171	15	18.5	2.1	4.5	92

*Rams marked with asterisk refer to the number of 2.0 lb-2.0 in. rams; others refer to the standard 14 lb-2.0 in. rams.

**Ave. of 3 readings on top and 3 readings on bottom of specimen.

The relationship between maximum green compressive strength and average mold hardness in clay-saturated sands has been proved.[2] This relationship of maximum green compressive strength to mold hardness is satisfied in the 10 and 12 per cent western bentonite mixtures in Fig. 6 (lower curve), but not in the 8 per cent western bentonite mixture of Fig. 4 (lower curve).

Since the higher clay content sands are clay-saturated, it is possible to achieve maximum contact area for shear strength within the mass and, therefore, higher tensile strength is obtained at the higher densities. The effect of higher clay content in clay-saturated sands then is to permit the sand to be rammed to higher tensile and shear strengths and mold hardness.

A comparison of lower clay content sands with those of higher clay contents can be made with the data in Table 4 for 6 per cent western bentonite mixtures. These data are plotted in Figs. 7 and 8. Figure 7 shows that tensile strength is proportional to shear strength, but reaches a maximum at about 4.5 to 5.0 psi shear strength or below, and then levels off. In Fig. 7, a solid line curve is reproduced from Fig. 3 for 8 per cent western bentonite mixtures. Comparison of the data on Fig. 7 show that at low shear strength, tensile strength for the two different clay levels is virtually the same.

However, as green shear strength increases with increasing ramming, the tensile strength levels off at between 2.0 and 3.2 psi tensile strength beyond 4.5 psi shear strength for the 6 per cent western bentonite mixture. At 8 per cent western bentonite, tensile strength levels off at 3.0 to 5.3 psi beyond 6 psi shear strength. In mixtures containing 10 to 12 per

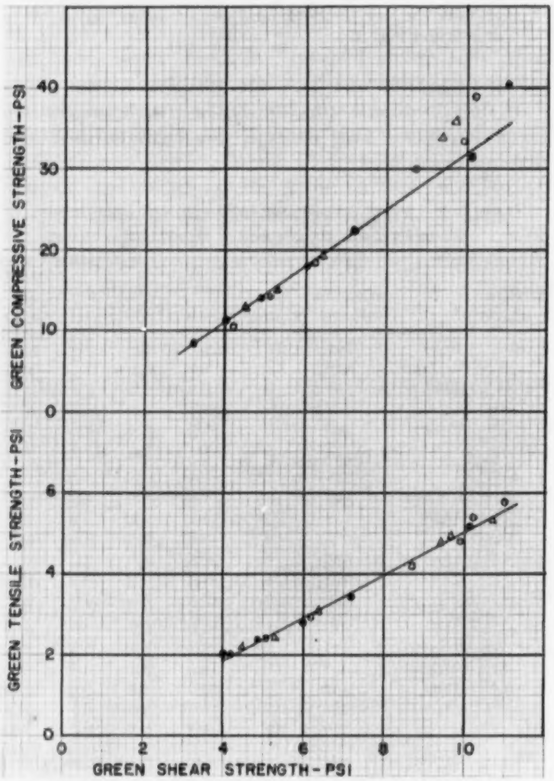

Fig. 5 — Relationship of green tensile and compressive strength to green shear in sand bonded with 10 to 12 per cent western bentonite. Data of Table 3.

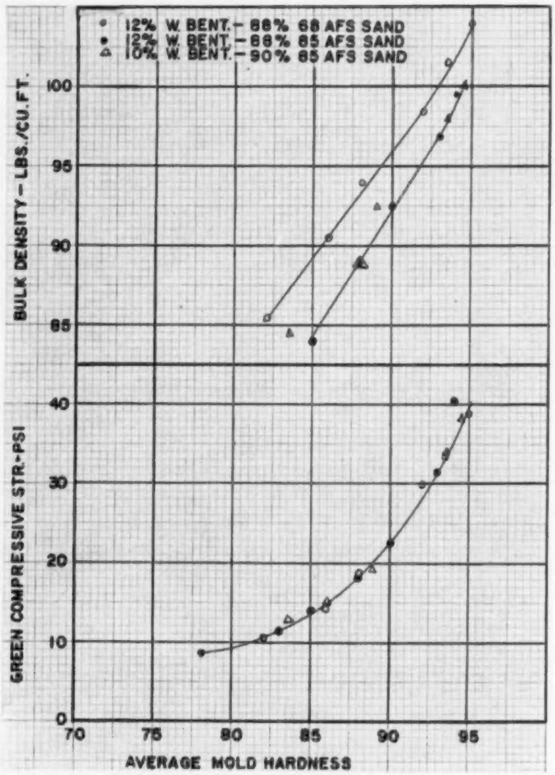

Fig. 6 — Relationship of green compressive strength and bulk density to mold hardness of sands, listed in Table 3 and Fig. 5.

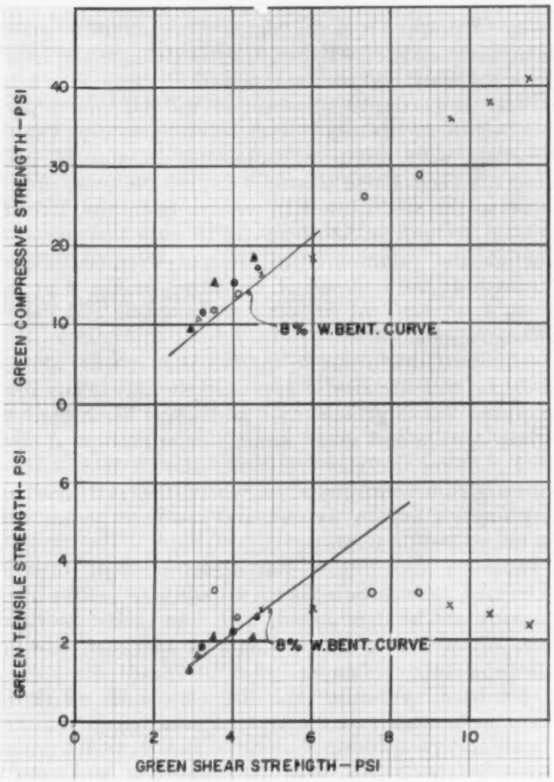

Fig. 7 — Relationship of green tensile and green compressive strength to green shear strength of sands bonded with 6.0 per cent western bentonite. Data of Table 4.

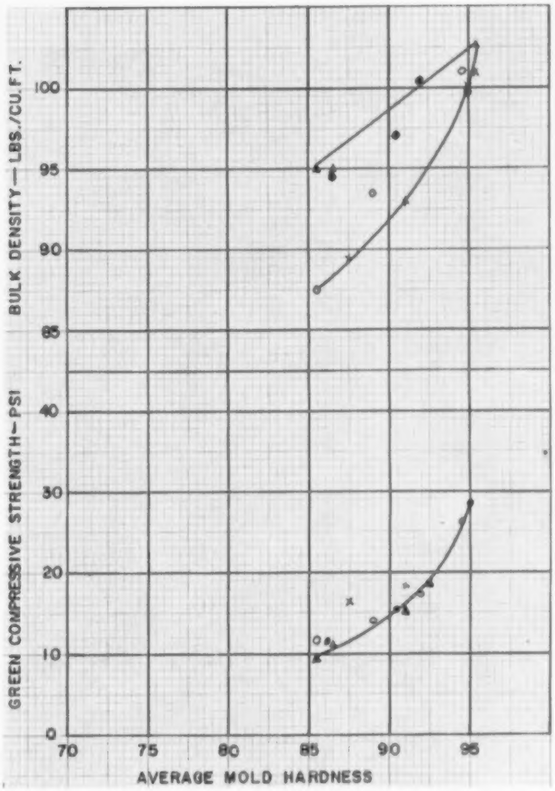

Fig. 8 — Relationship of green compressive strength and bulk density to mold hardness of sands, listed in Table 4 and Fig. 7.

cent western bentonite, tensile strength does not level off even at 5.8 psi tensile strength and 11.0 psi shear strength, the limit of these tests. Further, it may be noted in Fig. 7, that tensile strength of the 6 per cent western bentonite mixtures actually falls off beyond 6 psi shear strength with increasing ramming.

This effect is due to elastic rebound, caused by ramming when particle packing and particle contact begins within the specimen. In fact, some test specimens rammed to high density will actually fail in tension during ramming. Elastic rebound causes the specimen to fracture during the ramming operation, and it is not possible then to get a tensile strength test result. Thus, the effect of ramming cannot be considered independently of the clay content of the sand.

CLAY TYPE EFFECT

Southern bentonite and fire clay bonded sands were studied in the same way. Table 5 reports data for several mixtures containing 8 per cent southern bentonite, alone and with additives. The data in Table 5 are plotted in Figs. 9 and 10. Figure 9 shows the same relationship reported earlier for 8 per cent western bentonite mixtures, Fig. 3. Since the relationships of green shear, tensile and compression strengths, mold hardness and bulk density are the same as those reported for western bentonite earlier, the conclusions are the same and will not be repeated.

Some 10 and 12 per cent southern bentonite mixtures with 85 AFS sand were also tested. The points of data relating green shear strength with tensile and compressive strength are plotted in Fig. 11, and com-

TABLE 5 — GREEN PROPERTIES OF 8% SOUTHERN BENTONITE MIXTURES

Mixture and Symbol	Spec. Wt., grams	No. Rams*	Green Strength, psi Comp.	Tens.	Shear	Hardness**
20-△.	132	15*	9.3	1.6	3.2	79
8% S. bent.	135	1	10.1	1.8	3.5	80.5
92% 85 AFS sand	149.5	3	21.3	3.6	6.3	91
3.2% H_2O	160	7	33.7	5.4	8.5	94.5
21-▲.	142	2	13.0	1.9	3.8	84.5
8.0% S. bent.	155	3	14.0	2.3	4.1	85.5
92% 85 AFS sand	165	10	29.5	3.3	6.9	94.0
4.60% H_2O						
23-o.	136	26*	12.0	2.0	3.8	84.5
8.0% S. bent.	144	2	14.1	2.3	4.3	86.5
91% 85 AFS sand	149	3	20.5	2.9	5.8	90
1% carbonized	154	9	34	4.15	8.3	94
cellulose	164	13	43	4.20	8.4	95.5
3.8% H_2O						
24-●.	135	19*	10	1.7	3.3	83
8.0% S. bent.	142	2	14.7	2.3	4.2	87
91% 85 AFS sand	147	3	18.3	2.7	4.9	89
1% wood flour	155	5	24.5	3.2	5.9	92.5
4.1% H_2O	160	10	35	3.5	8.2	94.5
	165	17	42.5	3.4	8.7	95.5

*Rams marked with asterisk refer to number of 2.0 lb-2.0 in. rams; others refer to standard 14 lb-2.0 in. rams.

**Average of 3 readings on top and 3 readings on bottom of specimen.

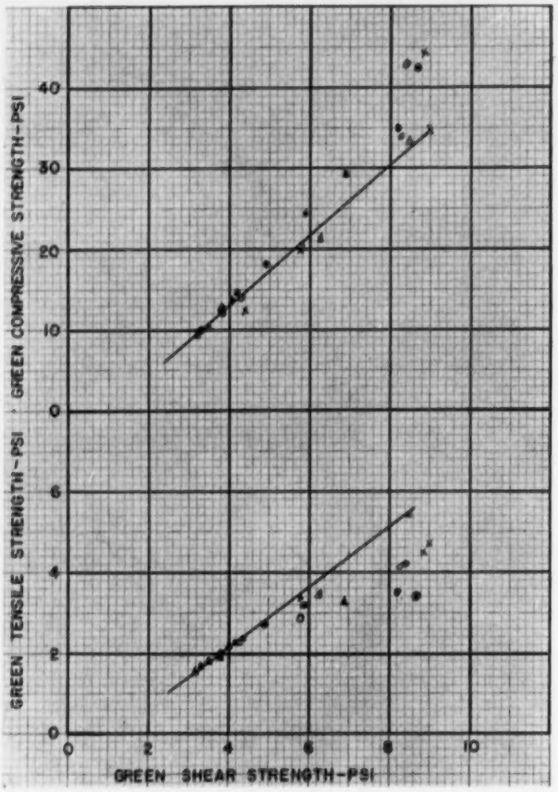

Fig. 9 — Relationship of green tensile and green compressive strength to green shear strength of sands bonded with 8 per cent southern bentonite. Data of Table 5.

pared with the curves for western bentonite. Figure 11 shows that this higher clay content southern bentonite mixture displays the same relationships and range of properties as the higher clay content western bentonite sands. Therefore, the conclusions are held to be the same, and are not repeated.

The properties of mixtures at the 4.0 and 6 per cent southern bentonite level are reported in Table 6, along with mixtures containing 10 and 15 per cent fire clay. These mixtures display the same properties as the mixture low in western bentonite. Green tensile strength is below 2.5 psi in each mixture, although the values are still related to green shear strength at the low end of the curve in Fig. 3 or 9. Even at 15 per cent fire clay, green tensile and shear strengths remain low.

However, this is due to the fact that it takes about 25.0 per cent fire clay to approach the clay saturation required for higher tensile and shear strengths.[2,3] Green tensile and shear strength relationships at the 25.0 per cent fire clay level were also studied in this investigation, and found to show the relationship previously cited for western and southern bentonites at the saturation level.

Table 6 also reveals that tensile strength of the low clay, low tensile strength mixtures could frequently not be determined. This was caused by rupture of the 2.0 x 2.0 in. diameter specimen within the tube during ramming.

Southern bentonite and fire clay sand mixtures have been shown to display the same green tensile, shear and compression strengths and mold hardness relationships, as discussed in connection with west-

TABLE 6 — GREEN PROPERTIES OF SAND MIXTURES CONTAINING SOUTHERN BENTONITE OR FIRECLAY

Mixtures	Spec. Wt., grams	No. Rams*	Green Strength, psi Comp.	Tens.	Shear	Ave. Mold Hardness**
25. 4% S. bent.						
96% 85AFS sand	155	3	10.8	1.4	2.5	87.5
2.50% H_2O	165	12	18.7	1.6	3.7	93.5
26. 4% S. bent.	152	2	15.5	2.0	3.1	90
96% 85AFS sand	157	5	19.5	2.4	3.7	93.5
2.0% H_2O	160	8	22.5	2.2	3.85	94
27. 6% S. bent.						
96% 85AFS sand	150	3	18	2.3	4.1	89
2.6% H_2O	155	5	22	2.5	4.6	92
28. 10% fire clay	168	3	9.5	Rebound failure	2.4	86
90% 85AFS sand						
3.8% H_2O	178	12	17	1.5	3.2	93
29. 10% fire clay	170	3	6.6	Rebound failure	1.8	81
90% 85AFS sand						
4.7% H_2O	180	9	10.3	1.5	2.4	87
30.	177	3	7.2	Rebound failure	2.7	84.5
15% fire clay						
85% 85AFS sand	184	6	9.5	1.5	3.4	87.5
5.8% H_2O	189	11	15.9	1.7	3.6	90

*Number of standard 14 lb-2.0 in. rams.
**Ave. of 3 readings on top and 3 readings on bottom of specimen.

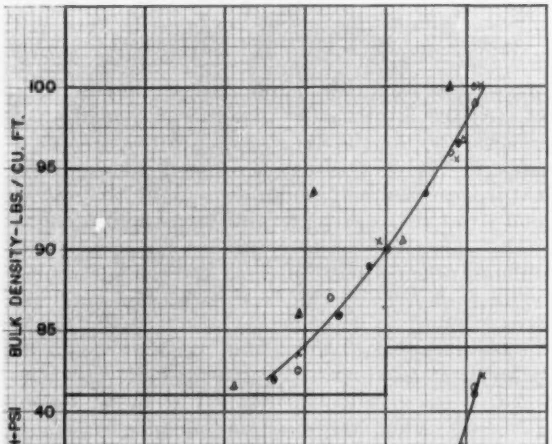

Fig. 10 — Relationship of green compressive strength and bulk density to mold hardness of sands, listed in Table 5 and Fig. 9.

ern bentonite. Southern and western bentonite display almost identically equivalent green properties, as pointed out in Figs. 9-11. This equivalence is also displayed by fire clay, but requires a substantially higher clay percentage. A total of ten different commercially available clays were tested, and found to show the same relationships. However, other investigators[4] have stated that there are some clays which display different relationships although the principles are the same.

BASE SAND EFFECT

The effect of sand fineness and sieve analysis on green tensile and shear strengths was investigated within present practical limits. Sands varying in fineness from AFS 49 to AFS 85, are represented in Tables 1 through 6. Silica and bank sands are also included. However, all these sands were of the 3 to 5 screen sieve distribution and sub-angular shape common to many foundry sands. Data on the standard AFS 50 sands have been reported,[4] and these data show that the same principles apply. However, no sands with an abnormally high percentage of fines were studied.

With reference to fineness and sieve analysis, no effects on the relationship of green tensile, shear strength, etc., were noted. This seems likely, especially at 6 per cent or more of bentonite, since the green properties are largely determined by the shear strength of the clay-water mass separating the sand grains. The dominating effect of the clay-water cement increases at higher clay contents. However, at low clay content the sieve analysis might have a noticeable effect. The low clay content mixtures at 4.0 per cent and below were not studied for such an effect.

TENSILE TEST LOADING RATE

The rate of loading can affect the values obtained in tensile testing. Two rates were studied in the investigation. The data in Tables 1 through 6 and Figs. 1-11 were obtained with a loading rate of 0.32 lb/sq in./sec, using a machine of the make shown on p. 92 of the AFS SAND HANDBOOK. A lower rate of loading of 0.062 lb/sq in./sec was found to develop tensile strengths about 10 per cent higher than those reported in this work. Slippage of the specimen in the specimen tube occurred during the tests with the slower rate of loading.

CELLULOSE ADDITIVES EFFECT IN FOUNDRY SANDS

Mixtures 9, 10, 23 and 24, reported in Tables 2 and 5, contained cellulose additives. Mixtures 9 and 23 both contained 1 per cent carbonized cellulose and 8 per cent western or southern bentonites, respectively. Mixtures 10 and 24 both contained 1 per cent wood flour and 8 per cent western or southern bentonites, respectively. The green tensile, shear and compression strengths and mold hardness relationships were not affected by the additives present. However, the carbonized cellulose permitted a higher tensile strength to be reached by ramming.

A number of foundry sands containing additives

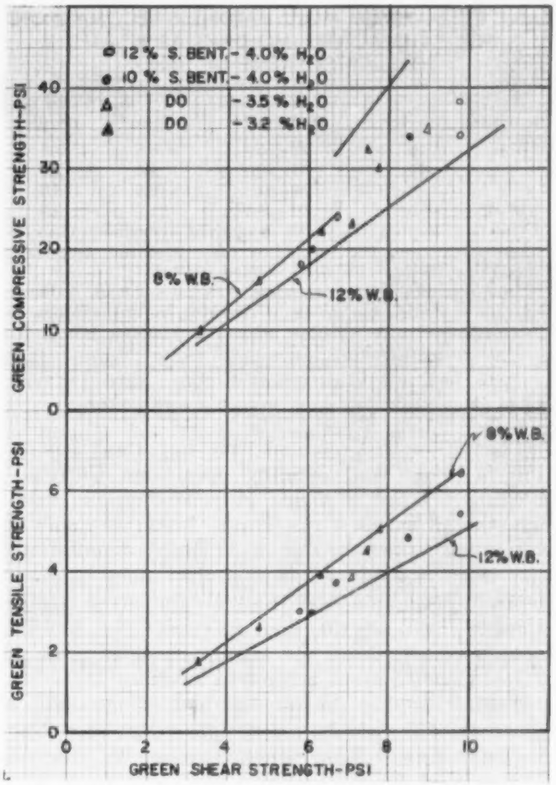

Fig. 11 — Relationship of green tensile and green compressive strength to green shear strength of sands bonded with 10 to 12 per cent southern bentonite.

also were studied, with no deviation from the principles studied. Typical values for a foundry sand based on a mixture containing 6 per cent bentonite, 2 per cent sea coal, 1 per cent carbonized cellulose and 85 AFS sand are cited (Table 7). Comparison of the data in Table 7 for a foundry sand should be made with the data for a new 8 per cent western bentonite mixture in Figs. 3 and 4. Such comparison shows that the combination of sea coal and carbonized cellulose has the effect of causing a 6 per cent western bentonite mixture to have properties similar to an 8 per cent mixture.

This is probably due to the contribution of the additives to extending or increasing the effective amount of plastic bonding from the clay-water additive mixture. Generalizing, the additives studied do not alter the principles of green property relationships in foundry sands.

TABLE 7 — GREEN PROPERTIES OF A FOUNDRY SAND

Mixture	Spec. Wt., grams	No. Rams*	Green Strength, psi Comp.	Tens.	Shear	Ave. Mold Hardness
6% W. bent.	134	20*	9.8	1.55	3.0	82.5
2.0% sea coal	142	2	12.1	2.1	3.9	87
1.0% carbonized	148	3	16.5	2.6	4.4	88.5
cellulose	156	7	27.5	3.6	6.5	93
3.3% H_2O	159	9	33'	3.6	7.3	94
	162	15	40.5	3.6	8.7	95.5

*No. of 2 lb-2.0 in. rams; all others are 14 lb-2.0 in. rams.

TABLE 8 — MAXIMUM MOLD HARDNESS RECOMMENDED FOR SATISFACTORY MOLDING AS RELATED TO CLAY CONTENT OF SAND*

Clay, %		Limiting Mold Hardness**	Limiting Strength, psi	
Bentonites	Fire clay		Shear*	Tensile*
4	10	80 - 85	3.5	1.8
6	15	85 - 89	4.0	2.5
8	—	89 - 91	6.0	3.6
10-12	—	93 - 95+	11.0	5.8

*This table applies specifically to sands of low enough moisture content to have good flowability (i.e., 10 to 30% free water according to the calculation method of Ref. 1).

**Limit does not refer to standard AFS 2.0 x 2.0 in. diameter, 3 ram specimen, but refers to ramming to this hardness or strength level with whatever amount of ramming is required in specimen or mold.

APPLICATION TO MOLDING OPERATIONS

The principles presented have important application in green sand molding operations. Currently, molding practice is aimed at producing the maximum mold hardness obtainable from the molding equipment. However, this investigation demonstrates that there is a maximum desirable mold hardness, depending on the clay content (or green tensile strength limit) of the sand mixture. The limiting mold hardness, shear and tensile strengths limit, as related to clay content, is listed in Table 8.

When ramming (by any method of molding) is practiced to a mold hardness higher than that listed in Table 8, the consequence is danger of cracking of the mold due to residual stress or spring back from the applied molding forces. For example, if a molding sand containing 4.0 per cent clay is molded on powerful molding equipment to hardnesses over 90, the mold is likely to crack, drop or hang-up on the pattern. Unless such a low clay content sand is used at a high moisture content where it is quite sticky (50 to 100 per cent more than calculated moisture[1]), these molding problems will develop.

At high moisture contents it is not possible to achieve the higher mold hardnesses, because the mixture will not develop sufficient compressive strength (or shear strength) to cause a high hardness regardless of the amount of power applied. The sand may then have sufficient deformation to relieve residual stresses, and therefore, the mold may not crack although drops can still occur due to low tensile strength.

On the positive side, the data in Table 8 show that a clay-saturated sand is one that is best suited for producing high hardness molds (90 to 95 mold hardness) and high strength molds. Powerful molding equipment can then be used to develop high strength molds, which can be drawn from patterns without mold failure. The sand can develop adequate tensile strength for pattern drawing, and residual stresses from molding forces will not cause cracking of the mold.

There are of course other reasons for an adequate amount of clay used in the sand, which are concerned with the behavior of the mold when the metal is poured. However, from the standpoint of green tensile strength, there is no gain in ramming low clay content sands to high mold hardness, since no significant increase in tensile strength is obtained. This ramming limitation does not apply to the high clay content sands.

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HOT CRACKING TEST FOR LIGHT METAL CASTING ALLOYS

By E. J. Gamber

ABSTRACT

A simple and reproducible test for determining the relative resistance to hot cracking of aluminum and magnesium casting alloys is described. This test is capable of assessing a wide range of cracking susceptibility, yet it possesses excellent sensitivity to small differences in cracking tendency. It is based on the fact that the probability for hot cracking to occur is greatest at a sharp internal angle, and diminishes as fillet radii of increasing sizes are provided.

Small specimens, termed "U" castings, are cast in a dry sand mold. The castings have the shape of thin elongated channel sections with short upright ends. Individual molds containing eight castings having variations in fillet radius or casting length produce a wide range of conditions governing hot cracking susceptibility.

Relative hot cracking ratings obtained from tests on various commercial aluminum and magnesium casting alloys are in good agreement with foundry experience, and appear superior to ratings based on cooling curve analysis or various ring mold tests employed by other investigators.

INTRODUCTION

A potential hot cracking problem exists whenever contraction is restrained while castings cool in molds. Both designers and foundrymen recognize the problem, and exercise known preventive measures such as providing generous fillet radii and draft angles, avoiding abrupt changes in section sizes and controlling solidification patterns and thermal gradients. Stresses that result from restrained contraction can be minimized in sand casting operations by selecting proper mold materials, and in permanent mold or die casting operations by controlling removal or ejection times.

Although design and operational precautions are effective, they will prove inadequate unless the proper alloy has been selected. Consideration also must be given to the cracking susceptibility of alloys.

Since hot cracking has been a problem frequently encountered by foundrymen, it has been the subject of numerous investigations. Various testing methods have been devised to study the influence of contributing factors.

The existing tests had limited ranges, low sensitivity or provided poor correlation with experience, therefore, they were inadequate. A test was desired that would enable the evaluation of many alloys having a wide range in resistance to hot cracking, yet one that would possess the sensitivity required for evaluating the effects of composition variations in specific alloys.

A testing method was developed which satisfied these requirements. It has been used successfully to evaluate the resistance to hot cracking to both aluminum and magnesium casting alloys, and has provided a reliable and useful tool for alloy development work.

TEST AND PATTERN EQUIPMENT DESCRIPTION

The hot cracking test selected consists of casting eight small specimens in a single dry sand mold. In Fig. 1, a test casting, termed a "U" casting, is shown. The rectangular cross-sections are $\frac{3}{4}$-in. wide and $\frac{3}{8}$-in. thick, and the length of the castings can be varied from 2 to 8 in. Fillet radii are $\frac{3}{4}$-in. at one end, and vary at the other end from $\frac{3}{4}$-in. to a sharp corner. The severity of the test depends upon both the fillet radius and the length of the casting. Tendency to crack is more pronounced with smaller radii and greater length.

Figure 2 shows the design of the patterns for test castings. A total of 14 aluminum patterns are used. These consist of eight that provide an 8-in. length but variable fillet radii, and six that provide a fillet radius of $\frac{3}{4}$-in. but variable lengths ranging from 2 to 7 in. Although only eight patterns are used for each mold, the greater number available permits selection of combinations depending upon the anticipated hot cracking resistance of alloys. Since eight castings are produced from each mold, a range of conditions can be surveyed rapidly and conveniently.

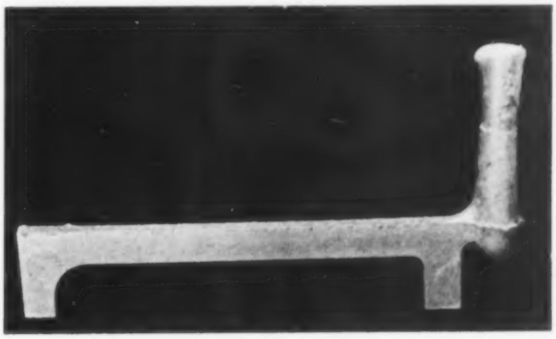

Fig. 1 — A "U" casting hot cracking specimen.

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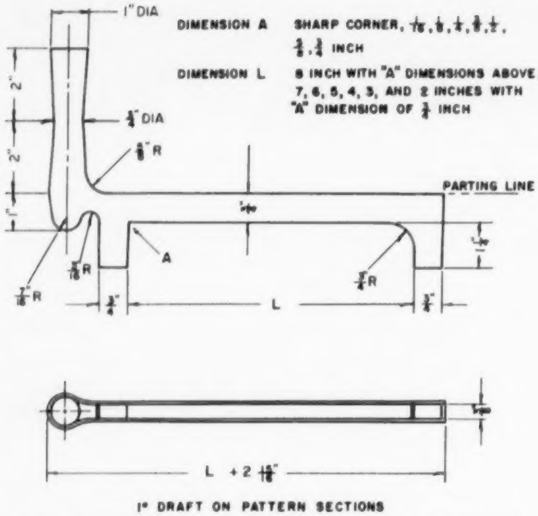

Fig. 2 — The design of patterns for the hot cracking test castings.

Figure 3 shows the patterns mounted 2 in. apart in an 18 in. long, 12 in. wide and 4 in. deep aluminum core box. The equipment was designed so the test castings are produced in the drag section of the mold. A sprue that also serves as a riser is located in the cope. The patterns can be easily removed from the box and are interchangeable, so that combinations including any eight of the 14 patterns can be used.

Test Procedure

Molds are made from carefully controlled baked core sand. The core mix selected should be strong to resist contraction stresses, yet have good collapsibility so castings can be easily removed from the mold without causing further cracking. A mix consisting of round grained washed silica sand bonded with urea formaldehyde is used. The sand should have an AFS grain fineness number of about 85. After baking, the core sand molds should exhibit a surface scratch hardness of about 90.

For the tests to be described, molds were prepared on a jolt, roll-over and draw machine. Use of the machine provided hard uniform packing of the sand, and assured a straight even draw that was essential to reproduce the fillet radii accurately.

During preparation of the drag, small cast iron chills are inserted at the side of the casting cavity. These cool the area at the intersection of the cross arms and the ends located away from the sprue. Through chilling in conjunction with the pouring and risering system employed, a solidification pattern was established which concentrated contraction stresses at the variable radii fillet. Since the combination sprue and riser is located near the variable fillet, that section remains hottest and therefore weakest during the solidification process.

Figure 4 shows an assembled mold. Usually three molds were cast of each alloy. Each of the test castings was individually poured. Heat losses during pouring were minimized by filling the cavities in successive order as rapidly as possible.

Aluminum Base Alloy Castings

Aluminum-base alloy castings were poured at 1350 F, and magnesium-base alloys were poured at 1425 to 1450 F. Castings were allowed to cool to room temperature before they were removed from the mold and then inspected for cracks. Occurrence of cracks was detected with the aid of a liquid dye penetrant, and also with a low power magnifying glass. A rating indicating resistance to hot cracking was assigned to the alloys on the basis of the most severe condition tolerated without cracking. No consideration was given to the length of the cracks.

The numerical system, shown in Table 1, was adopted to eliminate the necessity of specifying length and radius dimensions in reporting test results. Ratings were based on experience that indicated greater

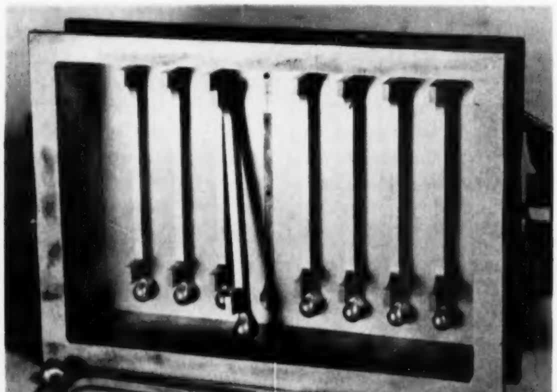

Fig. 3 — Core box used for production of the drag section of the hot cracking test mold. Interchangeable patterns are mounted in the core box and appear in the foreground.

Fig. 4 — An assembled hot cracking test mold. Each of eight test castings was individually poured. The overflow basin adjoining the sprue cups was provided to facilitate rapid pouring.

differences in resistance to hot cracking were depicted by varying fillet radii from ¾-in. to a sharp corner than by changing casting lengths from 8 to 2 in.

Test Results

Laboratory test results demonstrated the usefulness of the "U" casting test for comparing the hot cracking resistance of various commercial aluminum and magnesium casting alloys, as well as determining the effect of composition variations on specific alloys. The results, shown in Fig. 5, illustrate the ability of the test to detect the effect of composition variations in a specific alloy. Progressive improvements in hot cracking rating were obtained when silicon content of 195 alloy was increased from 0.2 to 3.0 per cent.

The improvement shown is in good agreement with foundry experience with sand casting alloy 195 (Al; 4.5 per cent Cu; 0.8 per cent Si) and permanent mold alloy (Al; 4.5 per cent Cu; 2.5 per cent Si). The higher silicon content of B195 alloy imparts greater hot cracking resistance for permanent mold castings. Composition limits shown by shaded areas, in Fig. 5, indicate the silicon content of the two alloys.

Ratings obtained and the nominal compositions of commercial aluminum and magnesium casting alloys subjected to "U" casting hot cracking tests are summarized in Tables 2 and 3. The alloys tested represent most of the types that are used in present-day foundry operations. The results demonstrate the ability of the test to differentiate between alloys with a wide range of resistance to hot cracking.

Of the aluminum alloys listed in Table 2, alloys 43, 333, 355, 356 and F132 displayed the greatest resistance to hot cracking, and alloys 195 and C612 exhibited the lowest resistance. The hot cracking ratings of aluminum alloys containing copper and silicon, 195, 108, B195, 319, 333 and F132, showed progressive improvement with increasing silicon content. In Fig. 6, the relationship between the hot cracking ratings for those alloys and their silicon content is shown.

Among the magnesium casting alloys tested, alloys EK41A and EZ33A exhibited the greatest resistance to hot cracking, whereas alloys AZ63A and ZK61A exhibited the lowest resistance. Of the magnesium alloys containing aluminum, AM100A was rated somewhat better than AZ92A and considerably better than AZ63A. Alloy HK31A was rated slightly better than AM100A and considerably better than HZ32A.

TABLE 1 — HOT CRACKING RATING SYSTEM

Smallest Fillet Radius Not Cracked, in.	Span Length, in.	Hot Cracking Rating
Sharp Corner	8	1.0
1/16	8	2.0
⅛	8	3.0
¼	8	4.0
⅜	8	4.5
½	8	5.0
⅝	8	5.5
¾	8	6.0
¾	7	6.3
¾	6	6.6
¾	5	7.0
¾	4	7.3
¾	3	7.6
¾	2	8.0
¾ Cracked	2	9.0

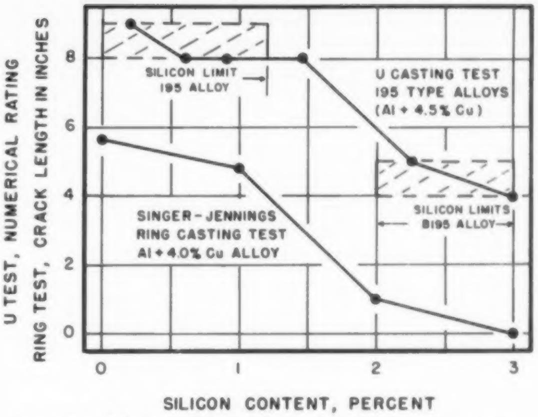

Fig. 5 — Silicon content effect on resistance to hot cracking of aluminum alloys containing 4.0 or 4.5 per cent copper measured by two test methods.

DISCUSSION

The "U" casting hot cracking test provides a simple and reliable means for evaluating the relative resis-

TABLE 2 — ALUMINUM CASTING ALLOY HOT CRACKING RATINGS AND NOMINAL COMPOSITIONS

Alloy	Composition, %* Cu	Si	Mg	Zn	Ni	Hot Cracking Rating**
43	—	5.0	—	—	—	1.0
F132	3.0	9.0	1.0	—	—	1.0
356	—	7.0	0.3	—	—	1.3
333	3.8	9.0	—	—	—	1.3
355	1.3	5.0	0.5	—	—	1.7
220	—	—	10.0	—	—	2.7
319	3.5	6.3	—	—	—	3.5
108	4.0	3.0	—	—	—	4.5
B195	4.5	2.5	—	—	—	4.5
142	4.0	—	1.5	—	2.0	5.0
C612	0.5	—	0.35	6.5	—	6.6
195	4.5	0.8	—	—	—	8.0

*Alloying elements — Aluminum, and normal impurities constitute the remainder.

**Smallest number indicates greatest resistance to hot cracking.

TABLE 3 — MAGNESIUM CASTING ALLOY HOT CRACKING RATINGS AND NOMINAL COMPOSITIONS

Alloy	Nominal Composition, %* Al	Mn (Min.)	Zn	Zr	Rare Earths	Th	Hot Cracking Rating**
EK41A	—	—	—	0.6	4.0	—	3.0
EZ33A	—	—	2.5	0.6	3.3	—	3.5
HK31A	—	—	—	0.7	—	3.2	4.2
AM100A	10.0	0.10	—	—	—	—	4.4
AZ92A	9.0	0.10	2.0	—	—	—	4.9
HZ32A	—	—	2.1	0.7	—	3.2	5.5
AZ63A	6.0	0.15	3.0	—	—	—	7.5
ZK61A	—	—	6.0	0.7	—	—	7.5

*Alloying elements — Magnesium, and normal impurities constitute the remainder.

**Smallest number indicates greatest resistance to hot cracking.

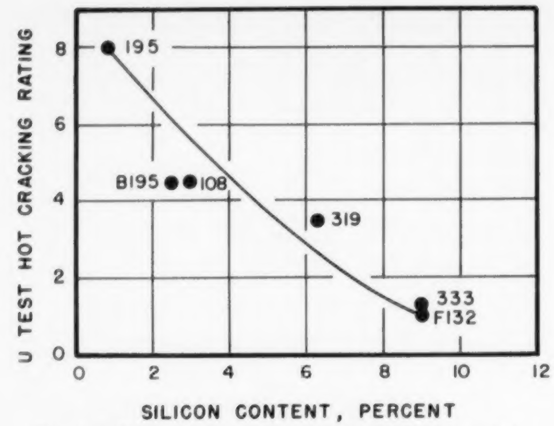

Fig. 6 — Silicon content effect on the resistance to hot cracking of commercial aluminum alloys containing 3.5 to 4.5 per cent copper.

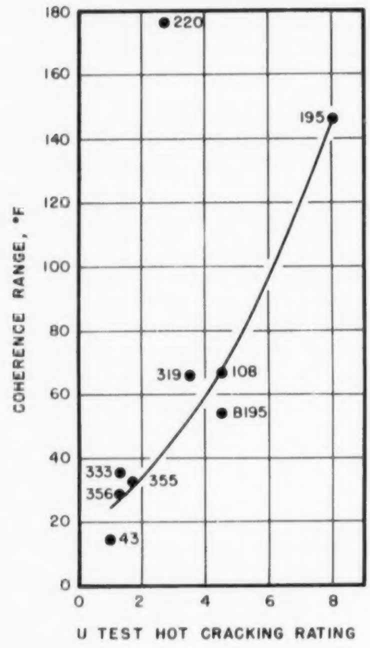

Fig. 7—Comparison between "U" test ratings for commercial aluminum casting, alloys and ratings based on cooling curve analyses.

TABLE 4 — "U" CASTING RATINGS AND MODIFIED RING TEST RATINGS COMPARISONS, MAGNESIUM CASTING ALLOYS

"U" Casting Tests		Modified Ring Tests**	
Alloys in Order of Resistance To Hot Cracking	Hot Cracking Rating*	Alloys in Order of Resistance To Hot Cracking	Proposed Classification*
AK41A	3.0	AM100A	1A
EZ33A	3.5	EK41A	1B
HK31A	4.2	AZ92A	1B
AM100A	4.4	EZ33A	2
AZ92A	4.9	HK31XA	2
HZ32A	5.5	AZ63A	2
AZ63A	7.5	HZ33A	3
ZK61A	7.5	ZK61A	3

*Smallest number indicates greatest resistance to hot cracking.
**Ref. 5.

tance to hot cracking of both aluminum and magnesium casting alloys. The ability to survey a wide range of testing conditions with one group of castings offers a distinct advantage. Since the test castings are produced in dry sand molds, and complete sets can be poured rapidly, variables such as fluctuations in mold and pouring temperatures and changes in alloy composition are avoided. The results obtained have been found reproducible, and have displayed little experimental scatter.

Hot Cracking Ratings

Relative hot cracking ratings are based entirely upon whether or not castings are cracked without giving consideration to the length of cracks. This provides a convenient and positive method for assessing resistance to hot cracking. Also the method is realistic because it conforms to foundry inspection standards, which usually specify that acceptable castings must be free from cracks.

The relative hot cracking ratings assigned to commercial alloys are in good agreement with foundry experience. Alloys having the best ratings are used to produce intricate castings. Greater susceptibility to hot cracking has been observed with alloys that are rated inferior by the test. Comparisons between ratings obtained from the "U" casting test and results reported by other investigators are of interest. Figure 7 compares ratings obtained from the "U" casting test with relative hot cracking ratings based upon cooling curve analyses.[1]

The cooling curve method was based upon the premise that metals form a coherent network before they solidify completely. By determining the difference in temperature between the formation of the coherent network and complete solidification, values termed coherence ranges were established for various alloys. Alloys having the smallest coherence range were considered to have maximum resistance to hot cracking.

Figure 5 shows data plotted from published results[2] of tests performed with the Singer and Jennings ring mold,[3] in which the effect of silicon and copper on the cracking susceptibility of aluminum alloys was determined. The curve shows the effect of silicon contents ranging from 0 to 3 per cent in an Al + 4 per cent Cu alloy. Comparison with "U" test ratings, shown in Fig. 5, reveals that the two methods give similar results, but the "U" casting test is capable of evaluating alloys that have greater resistance to hot cracking.

"U" Test Versatility

The versatility of the "U" test permitted the evaluation of magnesium casting alloys. Work performed by R. A. Dodd, W. A. Pollard and J. W. Meier[4] showed that the Singer and Jennings ring mold test was not severe enough for most commercial magnesium alloys. They developed modified ring tests which involved solidifying castings around steel cores or around carbon dioxide hardened sand cores. Table 4 compares ratings obtained from the "U" casting test, and classifications based on hot cracking sensitivity determined with the Dodd-Pollard-Meier test.

The two methods agreed on comparisons between alloys of the same general type. Both rated AM100A slightly superior to AZ92A and noticeably better than AZ63A, EK41A superior to EZ33A and HK31A superior to HZ32A. However, the two methods differed in the overall ratings of resistance to hot cracking. The "U" casting test rated alloys EK41A and EZ33A better than alloys AM100A and AZ92A. The Dodd-Pollard-Meier modified ring test rated alloy AM100A the least susceptible to hot cracking.

Alloys EK41A and AZ92A were rated equal and noticeably better than alloy EZ33A. The modified ring test placed both alloys EZ33A and AZ63A in the same general classification. The magnesium alloys containing thorium exhibited higher ratings with the "U" casting test than with the modified ring casting test.

Foundry experience has indicated that ratings from the "U" casting hot cracking test reliably indicate the hot cracking susceptibilities of alloys. Although significant differences between alloys AM100A and AZ-92A are not found in sand casting operations, alloy AM100A is considered to be less susceptible to hot cracking when poured in permanent molds. Alloys EK41A and EZ33A can be used for intricate permanent mold castings.

However, sufficient comparisons, on a production scale and in similar castings, have not been made to substantiate definitely the superiority of the rare earth containing alloys over Mg-Al and Mg-Al-Zn alloys that was indicated by the test.

SUMMARY

The "U" casting test provides a rapid and convenient method for surveying an extensive range of testing conditions. Alloys exhibiting a wide range of hot cracking susceptibilities can be assessed, yet minor changes in resistance to hot cracking resulting from composition variations in specific alloys can be determined. Since variables affecting hot cracking can be closely controlled, the results are reliable and can be reproduced with little experimental scatter.

The test is suitable for assessing both aluminum and magnesium-base alloys. Ratings depicting the relative hot cracking resistance of commercial as well as experimental alloys are in good agreement with foundry experience, and agree more favorably than ratings obtained by other methods.

ACKNOWLEDGMENT

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MARTENSITIC WHITE IRONS FOR ABRASION-RESISTANT CASTINGS

By T. E. Norman, A. Solomon and D. V. Doane

ABSTRACT

Martensitic white iron castings are extensively used to resist abrasive wear in a wide variety of applications. There are numerous variables in composition, production control, heat treatment and final structure which can influence the wear resistance and mechanical properties of such castings. It is important, therefore, in the interests of obtaining optimum service life, to recognize the effects of these variables and take the steps necessary for their proper control.

This paper deals with a number of the important characteristics of the martensitic white irons, together with studies which have been made by the authors on a number of the more important variables influencing their structure, wear resistance, mechanical properties and resultant service life.

Definition of Martensitic White Irons

To be technically accurate, the term "martensitic white iron" should probably be confined to those irons whose structure consists essentially of martensite and iron or alloy carbides. However, practically all such irons contain substantial quantities of retained austenite in their structure, and usually there is more austenite than martensite present. Some of these irons contain only austenite and carbides.

This retained austenite is normally metastable in character; therefore, it can transform to martensite or a martensite-like structure at the wearing face of the castings. This is brought about by the action of the abrasive forces, which cause plastic deformation and resultant transformation of some of the austenite at the wearing surface. Under the circumstances, it appears to be reasonably accurate to classify all such white irons as martensitic.

To be sufficiently inclusive, the authors suggest that martensitic white irons are those irons which contain a graphite-free structure of iron or alloy carbides and austenite or one of the low temperature transformation products of austenite. This definition will apply to all of the martensitic white irons dealt with in this paper.

MARTENSITIC AND PEARLITIC WHITE IRONS COMPARATIVE PROPERTIES

Composition and Structure

All white irons are basically iron-carbon alloys which solidify with a portion of the carbon in the form of primary carbides. In the iron-carbon system, this occurs when the carbon exceeds about 2.0 per cent. Practically all of the alloying elements, when added to this system, progressively lower the concentration of carbon necessary to form the primary carbides.

In white iron produced specifically for abrasion-resistant castings, the carbon normally exceeds 2.5 per cent, and is usually in a range of 3.0 to 3.6 per cent. Silicon contents are normally held under 1.0 per cent to avoid graphitization, and certain other alloying elements such as chromium are frequently added to further suppress formation of graphitic carbon in the structure. The structure of these irons immediately after solidification consists of primary carbides and austenite.

As the iron cools, this austenite transforms to pearlite, or to mixtures of ferrite and pearlite. This provides the basic structure of pearlitic white irons. Figures 1 and 2 show typical microstructures of pearlitic white irons. Figure 1 is an unalloyed iron, while Fig. 2 contains 5 per cent chromium.

Addition Alloys Effect

When certain alloying elements, notably nickel and molybdenum, are added in sufficient concentrations to white iron compositions, the transformation of austenite to pearlite during cooling of the iron after casting is completely suppressed. As a result, the austenite remains stable down to temperatures below which pearlite can be formed. During further cooling, the austenite in these alloyed irons may partially transform to low-temperature bainite and to martensite, although substantial proportions of this austenite normally are retained in the structure even after the casting has reached room temperature.

Such structures form the basis for the martensitic white irons. Typical microstructures of nickel-chromium white irons of this type, both sand and chill cast, are shown in Figs. 3 and 4, respectively.

It will be noted that in Figs. 1 through 4 the matrix (the principal phase in which another constituent is embedded) of the structure is iron carbide. This carbide has the formula Fe_3C or $(Fe,Cr)_3C$, and will be designated type C_1 for the remainder of this paper. Other carbide-forming alloying elements, such as manganese and molybdenum, also partially enter these type C_1 carbides. Type C_1 carbides have a relatively high hardness (800 to 1000 DPH under a 25-gram load), which contributes

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to abrasion resistance. Data from various sources indicate that these carbides are approximately as hard or slightly harder than quartz, which is one of the most common abrasives encountered in commercial service.

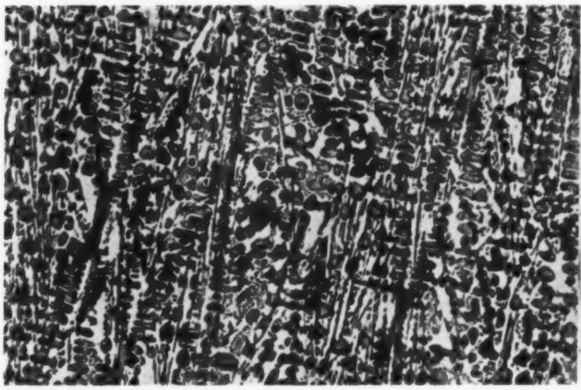
By increasing the chromium content of white iron compositions to concentrations over about 10 per cent, a new type of primary carbide with the formula $(Cr,Fe)_7C_3$ is formed in the structure.[1] This carbide, which will be designated type C_2 for the remainder of this paper, no longer forms the matrix phase, but instead is itself contained in a pearlite or austenite-martensite matrix. Figures 5 through 7 illustrate the typical structures obtained from compositions of this type.

Figure 5 is from a sand-cast test bar with a pearlitic matrix. Figure 6 is from a sand-cast test bar with a matrix which is largely austenite with small amounts of pearlite and martensite. Figure 7 is a similar composition except that it is chill cast. It shows extremely fine-grained primary carbides well surrounded by a matrix of austenite, with possibly some martensite.

By comparing the structures in Figs. 1 through 4 with Figs. 5 through 7, it is noteworthy that the matrix structure of the high chromium irons provides a much more favorable basis for good potential strength and toughness in the irons. In addition, the type C_2 carbides in Figs. 5 through 7 tend to be much finer grained than the type C_1 carbides in Figs. 1 through 4. This factor should further enhance the potential strength and toughness of high-chromium irons. Hardness of the type C_2 carbides is in the range of 1300 to 1800 DPH, which is well above the hardness of quartz. Consequently, high chromium irons should provide outstanding abrasion resistance in those types of service where quartz is the principal abrasive.

Commerical Compositions

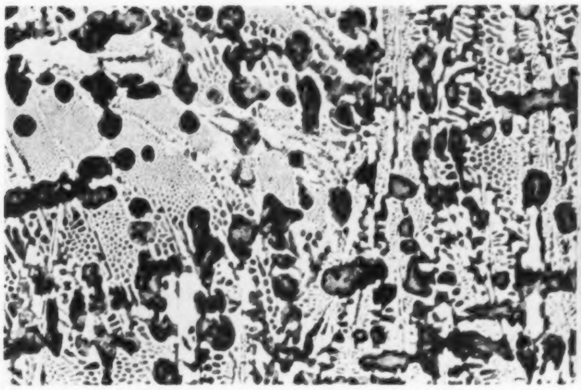
White irons containing type C_2 carbides form the basis of a series of commercially produced compositions containing between about 12 per cent and 30 per cent chromium. When the chromium content is near the lower end of this range, the addition of other alloying elements, such as molybdenum, is normally necessary to produce satisfactory suppression of pearlite in the matrix of these irons. When the chromium content is in a range of about 25 to



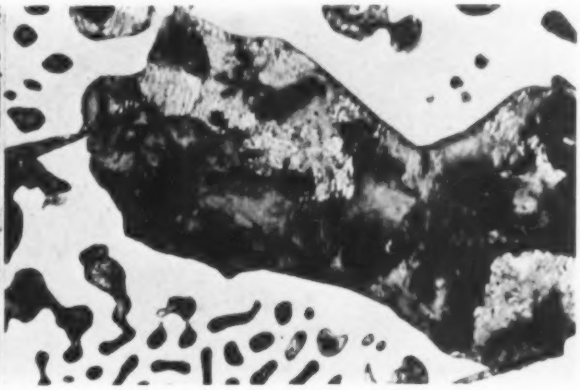
4 per cent picral etch. 100 ×.

4 per cent picral etch. 1000 ×.

Fig. 1. — Unalloyed white iron containing 3.6 per cent carbon, 0.7 per cent silicon, 0.8 per cent manganese. Structure shows coarse lamellar pearlite and ferrite in a type C_1 carbide matrix. This iron was chill cast to prevent graphite from forming in the structure.

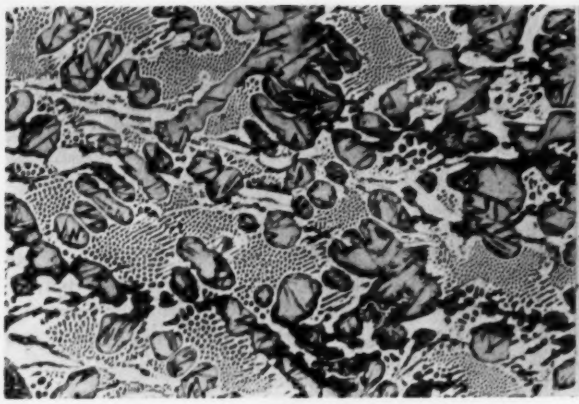


Picral and hot aqueous picric etch. 100 ×.



Picral and hot aqueous picric etch. 1000 ×.

Fig 2. — White iron containing 3.6 per cent carbon, 0.6 per cent silicon, 0.6 per cent manganese, 5.0 per cent chromium. Structure shows fine and coarse pearlite in a type C_1 carbide matrix, as developed near the center of a 2 in. diameter sand-cast ball, air cooled.



1 per cent picric, 5 per cent HCl in methanol etch. 100 ×.

Picral and hot aqueous picric etch. 1000 ×.

Fig. 3 — White iron containing 3.4 per cent carbon, 0.4 per cent silicon, 0.6 per cent manganese, 1.4 per cent chromium, 3.0 per cent nickel. Structure shows austenite-martensite in a type C_1 carbide matrix, as developed near the center of a 2 in. diameter sand-cast ball, air cooled.

30 per cent, and the carbon content is held below about 2.7 per cent, the use of other alloying elements to suppress pearlite may be unnecessary, except possibly in heavy-section castings.

A further important variable in the structure of these 12 to 30 per cent chromium irons must be considered, since it is easily possible to make them hypereutectic with respect to carbon. Hypereutectic low alloy white irons are quite rare and are difficult to produce commercially. When a 12 to 30 per cent chromium iron is hypereutectic, some of the type C_2 carbides solidify from the melt as relatively large needle-shaped crystals which tend to lower the toughness of the iron.

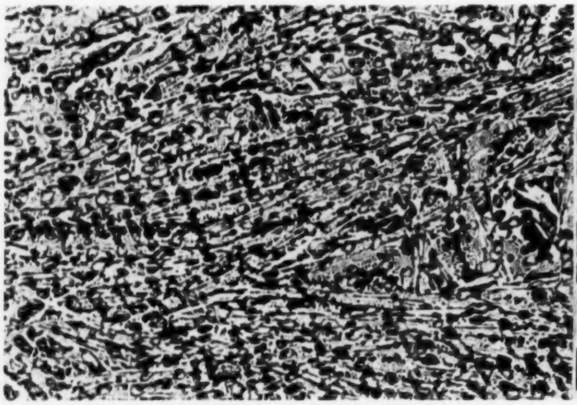
These needles also probably injure the abrasion resistance of the structure by crumbling or spalling microscopically under conditions where high abrasive pressures or some impact is involved. The structures of two such hypereutectic white irons, sand cast and chill cast, respectively, are shown in Figs. 8 and 9. The long carbide needles are particularly dominant in the sand-cast iron.

The eutectic composition range, with respect to carbon for a 12 per cent chromium iron, is between about 3.5 and 3.7 per cent carbon. For a 30 per cent chromium iron it is between about 2.4 and 2.8 per cent carbon. This is indicated by Kinzel and Franks,[2] and is in general agreement with the authors' own metallographic observations on such irons.

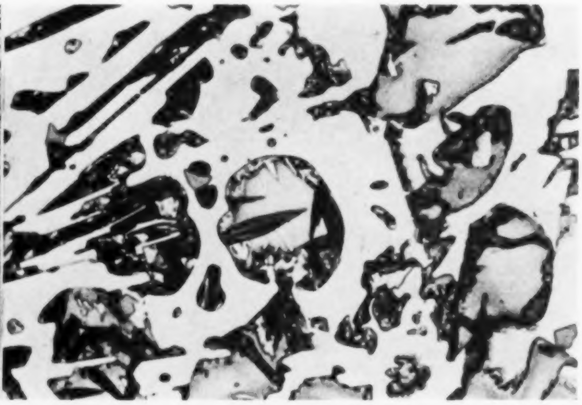
Response to Heat Treatment

It is possible to convert some white iron compositions from a pearlitic type, as-cast, to a martensitic type by reheating to suitable austenitizing temperatures, followed by a quench. Relatively mild heating and quenching rates must be used to avoid cracking or excessively high residual stresses in the casting. Still or moving air, molten salt baths and sometimes oil provide suitable quenching media.

The unalloyed pearlitic white irons have such shallow hardenability that it is practically impossible to convert them to a martensitic white iron, except in very thin sections, by reheating and quenching. With moderate additions of alloying elements such as manganese, nickel, chromium and molybdenum, the hardenability of these pearlitic white irons



1 per cent picric, 5 per cent HCl in methanol etch. 100 ×.

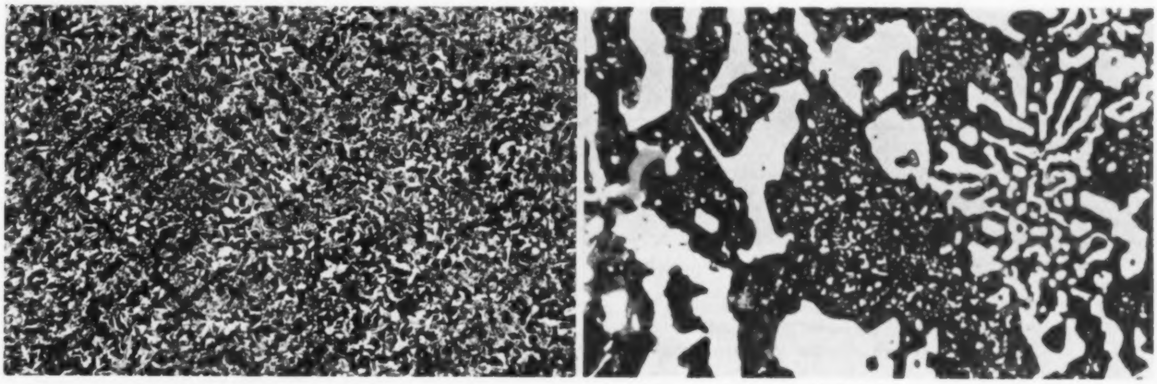


1 per cent picric, 5 per cent HCl in methanol etch. 1000 ×.

Fig. 4 — Chill-cast white iron containing 3.4 per cent carbon, 0.7 per cent silicon, 0.5 per cent manganese, 3.1 per cent chromium, 4.0 per cent nickel. Structure shows austenite-martensite in a type C_1 carbide matrix, as developed ¼-in. below the surface of a 2 in. chill-cast ball.

can be increased sufficiently to produce martensite in their structure when they are reheated and quenched. On abrasion-resistant castings with the matrix of type C_1 carbides, such heat treatments have seldom, if ever, been used commercially.

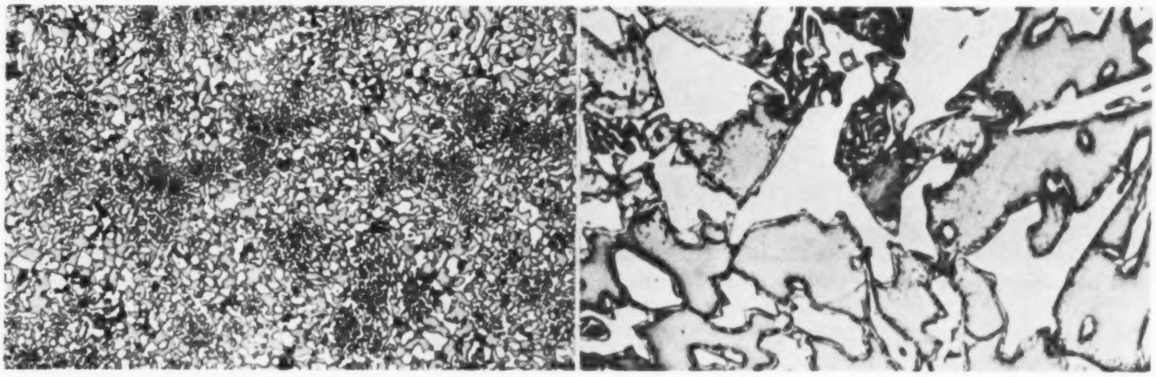
Probably there are a number of good reasons for this, which include the extra cost of such heat treatments and the tendency of such castings to crack or become brittle as a result of heat treatment. Limited investigations by the authors tend to confirm this.



4 per cent picral etch. 100 ×.

4 per cent picral etch. 1000 ×.

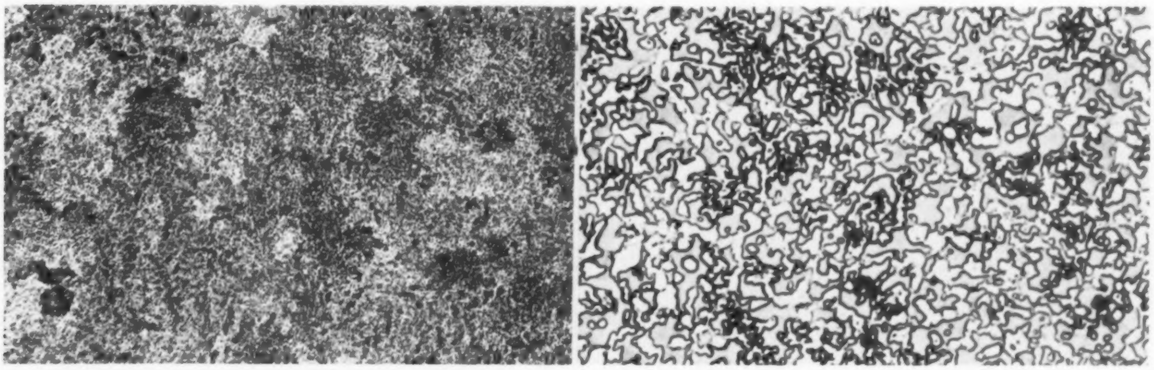
Fig. 5 — Sand-cast white iron containing 3.6 per cent carbon, 0.6 per cent silicon, 0.7 per cent manganese, 12.5 per cent chromium. Structure shows type C_2 carbides in a pearlitic matrix, as developed in a 1.2 in. diameter sand-cast test bar, transferred to a 1700 F holding furnace, then air cooled.



1 per cent picric, 5 per cent HCl in methanol etch. 100 ×.

1 per cent picric, 5 per cent HCl in methanol etch. 1000 ×.

Fig. 6 — Sand-cast white iron containing 3.5 per cent carbon, 0.4 per cent silicon, 0.8 per cent manganese, 16.0 per cent chromium, 3.0 per cent molybdenum. Structure shows type C_2 carbides in matrix which is largely austenite with small amounts of pearlite and martensite, as developed in a 1.2 in. diameter sand-cast bar, air cooled.



1 per cent picric, 5 per cent HCl in methanol etch. 100 ×.

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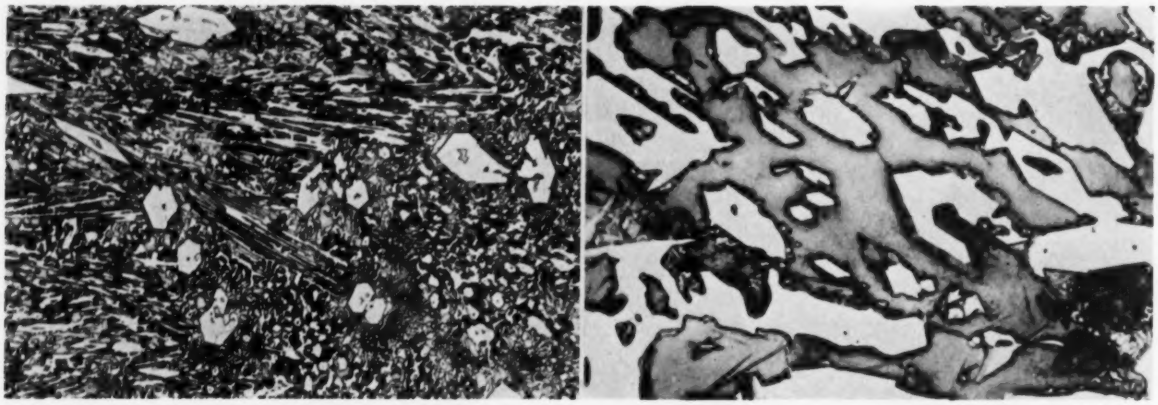
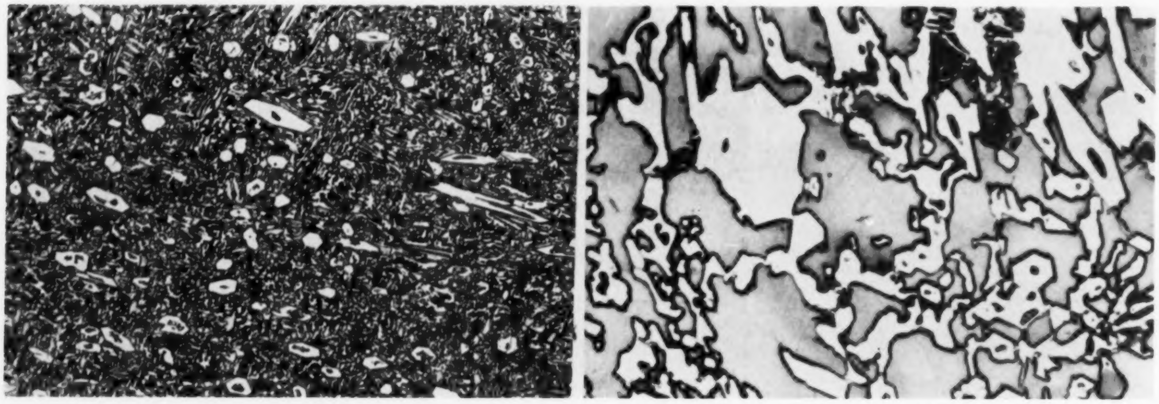
Fig. 7 — Chill-cast white iron from the same composition as Fig. 6. Structure shows type C_2 carbides in an austenite matrix, as developed in a 1.2 in. diameter bar cast in a graphite mold and air cooled.



1 per cent picric, 5 per cent HCl in methanol etch. 100 ×.

1 per cent picric, 5 per cent HCl in methanol etch. 1000 ×.

Fig. 8 — Sand-cast white iron containing 4.0 per cent carbon, 0.2 per cent silicon, 0.8 per cent manganese, 16.7 per cent chromium, 2.4 per cent molybdenum. Structure shows type C_2 carbides including (at 100 ×) the coarse needles typical of a hypereutectic iron. 1.2 in. diameter test bar.



1 per cent picric, 5 per cent HCl in methanol etch. 100 ×.

1 per cent picric, 5 per cent HCl in methanol etch. 1000 ×.

Fig. 9 — Chill-cast white iron containing 4.0 per cent carbon, 0.2 per cent silicon, 0.8 per cent manganese, 16.7 per cent chromium, 2.4 per cent molybdenum. Structure shows that chill casting results in much finer type C_2 carbides even in a hypereutectic iron. 1.2 in. diameter test bar.

The 12 to 30 per cent chromium white irons normally respond favorably to a reheat and quench type of heat treatment. Probably one of the principal reasons for this is that their type C_2 carbides are contained and well supported in a high carbon alloyed steel-type of matrix. Usually these heat treatments are applied to heavy section castings, which have such slow rates of cooling after casting that they tend to develop a pearlitic matrix in their as-cast condition.

Reheating and quenching (usually by an air quench) will convert this matrix to martensite, provided a sufficient concentration of alloying elements is present in this matrix to suppress pearlite formation. The effects of specific alloying elements on pearlite suppression in white irons will be discussed in later sections of this paper.

Figure 10 illustrates the structure obtained by heating a chute liner made from a 14 per cent chromium, 3 per cent molybdenum white iron to 1900-1950 F, followed by an air quench. The matrix in this structure consists of a dispersion of fine, spheroidized carbides in martensite. Relatively little retained austenite is present in this matrix. Hardness of the casting was 65 Rockwell C. In its as-cast condition (cooled in the mold), this chute liner has a matrix consisting of austenite and pearlite, and a hardness of 53 Rockwell C.

The primary type C_2 carbides in the high chromium irons are relatively unaffected by heat treatment. They appear to be extremely stable and retain their as-cast shape, quantity and high hardness after heat treatment.

Relative Abrasion Resistance

The principal reason for using the alloyed martensitic types of white iron in preference to unalloyed or low chromium pearlitic white irons lies in the fact that the martensitic white irons normally provide substantially better abrasion resistance. The degree of improvement varies, of course, with the application and type of abrasion.

In evaluating the relative abrasion resistance of any material it is advisable to classify the type of abrasion involved, since this usually has a pronounced effect

on the spread in wear rates obtained between a superior and inferior material. Avery[3] has classified abrasive wear into the following three types, which have provided a useful basis for the practical selection of suitable abrasion-resistant alloys.

1) Gouging abrasion, usually with impact.
2) High stress or grinding abrasion.
3) Low stress scratching abrasion or erosion.

Gouging Abrasion. White iron castings are not widely used in gouging abrasion because of the associated high impact or high structural stresses usually involved. There are, however, a number of uses which have provided comparisons between the pearlitic and martensitic types in Table 1. This table lists applications in which abrasive wear is believed to be largely of the gouging type.

The data in Table 1 indicate that the martensitic nickel-chromium white irons with type C_1 carbides are from two to four times as wear resistant as the unalloyed and low chromium pearlitic white irons when compared under conditions of gouging abrasion.

There is little available information as yet on the relative wearing properties of the high chromium martensitic irons and the unalloyed or low chromium pearlitic irons in gouging type of service. The high chromium irons have been extensively used as welded hard facings in this service, and they appear to have interesting possibilities as castings. Their potential strength and toughness should provide worthwhile advantages, which might allow the use of these irons under conditions where the low and medium alloy irons tend to fail by breakage or spalling.

TABLE 1 — RELATIVE LIFE OF PEARLITIC AND NICKEL-CHROMIUM (TYPE C_1 CARBIDE) MARTENSITIC WHITE IRONS IN GOUGING ABRASION[4]

		Relative Service Life	
Item	Application	Martensitic	Pearlitic
1	Crusher rolls for lead-zinc ore	3.8	1
2	Stamp shoes for copper ore	2.2	1
3	Grizzly disks for sizing coke	2.0-3.0	1
4	Hammers for pulverizing coal	2.5	1
5	Chute liners handling coarse ore	2.0-4.0	1
6	Cheek plates in a roll crusher	3.3	1
7	Scoop lips for ball mill feeder	4.0	1

TABLE 2 — LOW CHROMIUM PEARLITIC WHITE IRON AND HIGH CHROMIUM MARTENSITIC WHITE IRON COMPARISON ON A CHUTE LINER HANDLING MINUS 3 IN. SILICEOUS ORE

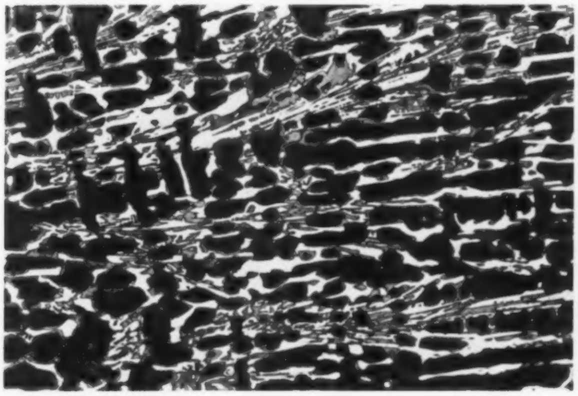
	Item and Description	
	1-Martensitic High Cr Iron	2-Pearlitic White Iron
Composition, %		
C	2.6	3.4
Si	1.5	0.5
Mn	1.1	0.5
Cr	14.3	1.0
Mo	3.0	—
Wear Rate, lb/1000 tons	0.22	0.43

The one known comparison between a martensitic high chromium iron and pearlitic white iron in gouging type of service is given in Table 2. Here a 14 per cent chromium iron had about twice the wear resistance of the pearlitic white iron. This performance could probably be further improved by increasing the carbon content of the 14 per cent chromium iron.

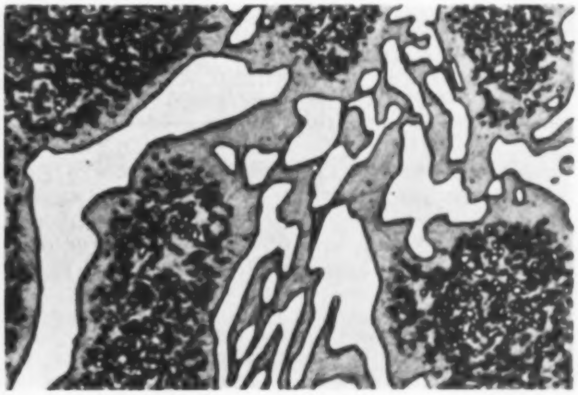
High Stress (Grinding) Abrasion. The use of both the pearlitic and martensitic white irons had been quite extensive in applications involving high stress abrasion. This type of abrasion is most commonly encountered in grinding of ores and industrial minerals. Principal wearing parts are grinding balls and rods, grinding mill liners and grinding rolls.

Table 3 gives the comparative wear rates of martensitic white iron balls in a number of ball mill grinding operations. These rates are compared to a relative wear rate of 100 for chill cast, unalloyed pearlitic white iron in the same service. In this table a rate of less than 100 indicates proportionately better abrasion resistance.

Table 3 indicates that hardness of the abrasive has a pronounced influence on relative wear rates. When hard minerals such as quartz are the principal abrasives, the spread in relative wear rates tends to be small, whereas when a softer mineral such as feldspar or hematite is the principal abrasive, the spread in relative wear rates is substantially greater. Possible



Hot aqueous picric etch. 100 ×.



Hot aqueous picric etch. 1000 ×.

Fig. 10 — Structure developed by heat treatment of a high chromium iron. This is from a chute liner 2 in. thick, containing 2.6 per cent carbon, 1.5 per cent silicon, 1.1 per cent manganese, 14.3 per cent chromium, 3.0 per cent molybdenum, reheated to 1900-1950 F and air cooled.

TABLE 3 — RELATIVE WEAR RATES OF MARTENSITIC AND PEARLITIC GRINDING BALLS IN HIGH STRESS (WET GRINDING) ABRASION

Item	Reference*	Casting Method	Service	Principal Abrasives	Wear Rate Relative to Rate of 100 for Chill Cast Pearlitic White Iron
Ni-Cr martensitic irons with type C_1 carbides					
1	5	Chill	Mo ore, 6 ft dia. mill	Quartz and Feldspar	64-68
2	5	Sand	Mo ore, 6 ft dia. mill	Quartz and Feldspar	58-62
3	6	Sand(?)	Raw cement, 7 ft mill	?	71
4	5	Sand	Au ore, 5 ft mill	FeMg Silicates	68
5	7	Chill	Cu ore, 7 ft mill, Plant A	Quartz	68-70
6	7	Sand	Cu ore, 7 ft mill, Plant A	Quartz	65-66
7	8	Chill	Cu ore, 7 ft mill, Plant A	Quartz	65**
8	8	Chill	Cu ore, 8 ft mill, Plant B	Quartz and Feldspar	59**
9	5	Sand	Cu ore, 6.5 ft mill, Plant C	Feldspar and Quartz	45-50
10	7	Chill	Fe ore, 5 ft mill	Hematite	41
11	7	Sand	Fe ore, 5 ft mill	Hematite	39
12	5	Sand	Feldspar, 3 ft mill	Feldspar	29-34
Cr-Mo martensitic irons with type C_2 carbides					
13	7	Chill	Mo ore, 9 ft mill	Quartz and Feldspar	54-59
14	7	Chill	Cu ore, 7 ft mill, Plant A	Quartz	55-57
15	7	Chill	Fe ore, 5 ft mill	Hematite	34

*References listed here are given at the end of the paper.
**These wear rates are based on large-scale consumption tests.

reasons for this are indicated and discussed in a previous paper by one of the authors,[9] and by other investigators.[10,11,12]

Martensitic white iron grinding balls have probably shown their most outstanding superiority over other materials in the dry grinding of cement clinker, where their wear resistance is reported to be from four to seven times that of martensitic high carbon steel balls.[4,6] Data on the relative wear of martensitic and pearlitic white iron balls in this service have not been found, so comparisons in the grinding of cement clinker are not available for inclusion in Table 3.

Some typical relative wear rates of nickel-chromium and nickel-chromium-molybdenum martensitic white irons with type C_1 carbides are given in Table 4. These rates are, in most cases, based on averaged results from several sets of liners of each type, run under closely comparative operating conditions.

The data in Table 4, when compared to the results on balls in Table 3, indicate that somewhat greater improvement in comparative wear resistance is obtained by changing from a pearlitic to a martensitic iron in liners than is obtained in grinding balls. Quite possibly this is due to the effects of heavy section size. Low alloy and unalloyed pearlitic white irons normally contain rather coarse pearlite and considerable ferrite when made in heavy sections. These constituents have relatively poor wear resistance in high-stress abrasion.

Table 4 also shows the wider spread in relative wear rates when the softer minerals are ground, as was indicated in Table 3.

High chromium martensitic white irons with type C_2 carbides offer interesting possibilities under conditions of high-stress abrasion. Use of the high-chromium irons in such applications is relatively new, so little comparative data on their wearing properties are available at this time. Preliminary field reports indicate they have definitely better wear resistance than the martensitic irons with type C_1 carbides. This is further indicated by an evaluation test in the grinding mills at the authors' company. Relative wear rates obtained in this test are given in Table 5.

The procedures used in conducting the wear test for Table 5 are described in detail in a previous paper.[9] They involve the production and testing of large (5-in. diameter) marked balls with structures equivalent to those produced in heavy-section liners of the same compositions. All test balls were run in the same mill at the same time to ensure that each composition was exposed to identical service.

On the basis of the wear rates in Table 5, it appears that the high chromium-molybdenum irons may have interesting economic possibilities for ball-mill liners in some types of service. Their better wear resistance must, of course, be sufficient to justify their normally higher alloy cost, except possibly in those cases where shutdown time for relining a mill represents an important item of cost.

TABLE 4 — WEAR RATES OF MARTENSITIC WHITE IRON BALL MILL LINERS WITH TYPE C_1 CARBIDES IN COMPARISON TO PEARLITIC LOW CHROMIUM OR UNALLOYED WHITE IRON

Item	Reference	Service	Principal Abrasives	Wear Rate Relative to Rate of 100 for Pearlitic White Iron
1	13	End Liners in 9-ft ball mill. Mo ore.	Quartz and Feldspar	50-60
2	8	Shell Liners in 8-ft ball mill. Cu ore, Plant B.	Quartz and Feldspar	45-50
3	8	Shell Liners in 10.5-ft ball mill. Cu ore, Plant D.	Quartz and Feldspar	45-50
4	4	Shell Liners in 7-ft ball mill. Cu ore, Plant E.	Feldspar	30 (approx.)
5	4	Shell Liners in 7-ft ball mill. Wet raw cement.	Limestone(?)	37

TABLE 5 — COMPARISON OF MARTENSITIC WHITE IRON LINER ALLOYS IN GRINDING SILICEOUS ORE

Item	Description and Heat Treatment	Composition, %						Carbide Type	Hardness Rc*	Abrasion Factor**
		C	Mn	Si	Cr	Mo	Ni			
1	Martensitic Cr-Mo white iron, heated to 1950 F, air cooled	2.8	1.0	0.6	15.0	3.0	—	C_2	66	89
2	Martensitic Cr white iron, heated to 2000 F, air cooled	2.7	1.0	0.6	26.0	—	—	C_2	64	98
3	Chill cast Ni-Cr-Mo white iron, cast, cooled in sand, tempered 425 F	3.2	0.7	0.5	2.0	1.0	3.0	C_1	59	107
4	Chill cast Ni-Cr white iron, cast, cooled in sand, tempered 425 F	3.0	0.5	0.4	2.1	—	4.5	C_1	55	116

*Average hardness on the worn surface after the wear test.

**Abrasion factor is the rate of wear relative to a rate of 100 for heat-treated high carbon Cr-Mo martensitic steel containing 1.0% carbon, 0.8% manganese, 6.0% chromium and 1.0% molybdenum. Note that the relative wear rates are on a different basis from those in Tables 3 and 4.

Low Stress Abrasion (Erosion). In erosive types of wear, where impact conditions are usually mild, the various types of white iron normally provide better abrasion resistance than any types of steel or other ferrous alloy. This is believed to be due to the presence of the large amount of carbides, which are normally present in white iron structures. The influence of these hard carbides in resisting erosive wear has been well demonstrated by Haworth[10] and by Avery and his associates.[3,14]

A comparison of relative wear rates of various white irons in erosive service is given in Table 6.

In Table 6 items 1 and 2 were most outstanding, and are the only two materials found to date which can compete economically with low chromium pearlitic white iron in this service. Probably the superiority of these two materials is due to the fact that they contain type C_2 carbides, which are substantially harder than the quartz in the ground-ore slurry. Similar results have been obtained by Haworth[10] and Avery[3,14] on their erosion tests with quartz abrasives, where the martensitic white irons with type C_2 carbides were found to be much superior to either the pearlitic or martensitic white irons with type C_1 carbides.

TABLE 6 — RELATIVE WEAR RATES OF PEARLITIC AND MARTENSITIC WHITE IRONS AND A STEEL FOR CLASSIFIER WEAR SHOES IN EROSIVE WEAR BY GROUND ORE SLURRIES

Item No.	Description	C, %	Hardness, Rc	Relative Wear Rate
1	Martensitic 15% Cr, 3% Mo iron, as-cast	3.3	58	28
2	Martensitic 27% Cr iron, as-cast	3.1	57	48
3	Martensitic 4% Ni, 2% Cr iron, as-cast	3.3	57	80
4	Pearlitic 1% Cr iron, as-cast	3.3	47	100
5	Martensitic Cr-Mo steel, heat treated	1.5	57	180

A comparison of items 3 and 4 in Table 6, which both contained type C_1 carbides, indicates that a small improvement was obtained by changing to a martensitic structure in these irons. The contribution of martensite to abrasion resistance in this wear shoe service appears to be of secondary importance in comparison to the effect of the carbides. This is further indicated by the relatively poor abrasion resistance of the martensitic steel (item 5) which was low in carbide content.

The relatively small contribution of martensite to abrasion resistance of white irons, as indicated in Table 6, is not in general agreement with the results from Haworth's and Avery's tests. For instance, in Haworth's laboratory tests, the 14 per cent chromium irons with a martensitic matrix (obtained by heat treatment) were much superior to the same irons (as-cast) with a pearlitic matrix. Also Avery's data indicate that nickel-chromium martensitic irons with type C_1 carbides had about three times the wear resistance of pearlitic low chromium iron in dry quartz sand erosion.

A further significant comparison is available from the service tests on blades in centrifugal abrading machines, as reported by Haworth.[10] His results for the white irons of approximately equal carbon content are summarized in Table 7.

In Table 7, a martensitic chromium molybdenum iron (item 6) with type C_2 carbides again shows best abrasion resistance, which is in line with the results in Table 6.

A comparison in Table 7 of the martensitic nickel chromium white iron (item 4) and the pearlitic un-

TABLE 7 — WEAR RATES OF PEARLITIC AND MARTENSITIC WHITE IRON AS-CAST BLADES IN A CENTRIFUGAL ABRADING MACHINE USING CHILLED IRON SHOT[10]

Item*	Material	% Composition				Carbide Type	Hardness Rc	Wear Rate (grams/hr)
		C	Cr	Mo	Ni			
6	Martensitic Cr-Mo Iron	3.1	12.1	1.8	—	C_2	52-56	1.7
4	Martensitic Cr-Ni Iron	3.0	1.2	—	4.1	C_1	49-53	2.8
2	Pearlitic Cr Iron	3.2	9.6	—	—	$C_1 + C_2$	51-54	7.4
1	Pearlitic White Iron	2.8	0.2	—	—	C_1	44-48	19.0

*Item numbers are those given in Haworth's original table.

alloyed white iron (item 1), which both contained type C_1 carbides, indicates that in this case the martensitic white iron is much superior to the pearlitic white iron. It is also superior to the pearlitic 9.6 per cent chromium white iron which probably contained a mixture of C_1 and C_2 type carbides.

Since the martensite in white iron is somewhat softer than quartz, its principal contribution to abrasion resistance may be in the support which it provides to the hard carbides in the structure, thus preventing them from crumbling or spalling microscopically under conditions of severe erosive wear. This support may be more necessary under conditions involving high velocity erosion, as in Haworth's and Avery's tests, than it is in low velocity erosion, such as existed on the classifier wear shoes in Table 6.

The results in Tables 6 and 7, together with those given by Haworth,[10] Avery[3,14] and others,[11,15] all indicate that high carbon martensitic white irons with type C_2 carbides provide outstanding resistance to erosive wear. This is further indicated by many service results on these irons in such parts as sand pump impellers, brick mold liners and linings for pipes carrying abrasive fluids. These 12 to 30 per cent chromium white irons are similar in many respects to high carbon modifications of the high carbon, high chromium tool steels, which have also been found to be resistant to erosive wear.

A high vanadium modification of these compositions has also been developed,[16] and is reported to be giving outstanding service in both cast and wrought wearing parts for sand slingers and shot-blasting machines.

The contribution of molybdenum to the abrasion resistance of high chromium irons is significant. The results from items 1 in Tables 5 and 6 and item 6 in Table 7, together with a result reported by Haworth,[17] on brick mold liners, attest to this. While the primary function of molybdenum in these irons is to suppress pearlite formation, it obviously has a further favorable effect on the properties of the carbides as well as the matrix.

Mechanical Properties

Martensitic and pearlitic white iron castings are generally designed for use in applications where high tensile strengths and a substantial degree of toughness are unnecessary. Mechanical properties, other than hardness, are seldom specified for these castings. As a consequence, a common basis for evaluation of these mechanical properties has not yet been adopted. These castings are, however, used in certain applications where a limited amount of breakage in handling, or premature failure in service, is tolerated in the interest of using a material with high wear resistance.

There are other applications where white irons are not now specified, but would be used if a greater degree of toughness could be assured. It should be well worthwhile, therefore, to make greater use of mechanical property tests on white irons. These could lead to the development of improved casting techniques, compositions and heat treatments designed to provide greater strength and toughness in the castings.

Hardness. Pearlitic white irons free from graphite will normally have a hardness range from about 325 Brinell (35 Rc) for low carbon (2.40 to 2.60 per cent) unalloyed compositions, to as high as 600 Brinell (57 Rc) for high carbon (3.50 to 4.00 per cent) moderately alloyed compositions. The martensitic white irons, because of their variable retained austenite contents, show an even wider range in hardness, from a low of about 300 Brinell (32 Rc) for low carbon fully austenitic compositions, to a high of about 70 Rc (beyond the upper limit of the Brinell test) for high carbon, high chromium irons heat treated to develop a high martensite, low austenite matrix.

Although, in general, there is little correlation between the hardness of these irons and their wear resistance, this correlation is not entirely lacking for a given type composition and heat treatment and a specific condition of service. However, the effects of composition, solidification rates, microstructure and heat treatment normally have shown much more influence on wear resistance than the actual hardness of the iron.

Tensile Properties. Due to the difficulties involved in machining and testing white iron tensile specimens, particularly when they are of the martensitic type, there is relatively little good information available from actual tests on tensile test bars. An exception to this is to be found in the data published by Flinn and Chapin.[18] Their observations, on a series of carefully run tests, from specimens sand cast in Y blocks, indicated the following on a series of iron containing 3.4 per cent carbon:

1) Pearlitic white irons containing 1.5 per cent chromium had tensile strengths of 34,000 to 46,000 psi. Plastic elongation prior to breakage was less than 0.0003 per cent.
2) Martensitic nickel-chromium white irons with type C_1 carbides had tensile strengths of about 32,000 psi in their untempered condition, and about 50,000 psi when tempered at 500 F. These irons showed a measurable amount of plastic elongation ranging from 0.0080 per cent in their untempered condition to 0.0044 per cent when tempered.
3) Martensitic nickel-chromium white irons containing 0.33 per cent graphitic carbon in their structures had about the same strength, and appreciably lower plastic elongation, than similar irons free from graphite.
4) Martensitic nickel-chromium mottled irons containing 1.57 per cent graphitic carbon had tensile strengths of 43,000 psi (untempered) to 50,000 (tempered) and corresponding plastic elongations of 0.0505 per cent and 0.0213 per cent, respectively.
5) Charpy impact strength of both the pearlitic and graphite-free martensitic irons on 0.707-in. square unnotched test bars was between 4.8 and 7.5 ft-lb. This increased to a range of 10.3 to 11.0 ft-lb in the nickel-chromium irons containing 1.57 per cent graphitic carbon.

Flinn and Chapin's data indicate that the martensitic nickel-chromium irons, when tempered at

500 F, are somewhat stronger and have greater ductility than the low chromium pearlitic irons. The ability of the martensitic irons to yield plastically, even by small amounts, is probably quite significant in any evaluation of their relative toughness.

Although appreciable quantities of graphite in the structure of nickel-chromium martensitic irons have a favorable effect on toughness, the presence of this graphite seriously damages the abrasion resistance of these irons. It is generally desirable, therefore, to avoid the formation of graphite in these martensitic irons.

Published data[19] on the comparative tensile properties of a martensitic white iron with type C_2 carbides, and a nickel-chromium martensitic white iron with type C_1 carbides, are given in Table 8.

It is evident from the data in Table 8 that the high chromium iron had substantially superior strength and ductility. This is probably due to the more favorable distribution of carbides in this type of iron.

Tensile Data Summary

To summarize the available tensile data, it is indicated that the pearlitic white irons tend to have the lowest strength and elongation, the martensitic white irons with type C_1 carbides are intermediate in these properties and the martensitic white irons with type C_2 carbides have the highest strength and elongation of these three types of white iron. These observations are further confirmed by the authors' tests on the transverse properties of these irons, and by experience with each of these types of iron in actual service.

Transverse Properties. Standard A.S.T.M. transverse test bars, 1.2 in. in diameter, broken on an 18-in. or 12-in. span, have frequently been used to determine the relative strength and toughness of white iron. The authors' results with tests of this type indicate that a fairly wide range of values may be experienced, even with supposedly similar white iron compositions and structures. In spite of this, definite trends are observable. The ranges in results obtained by the authors on various low chromium pearlitic irons, and a series of 12-16 per cent chromium martensitic irons, are given in Table 9.

The results in Table 9 indicate a general improvement in properties when irons of approximately equivalent carbon content are converted from a pearlitic type with type C_1 carbides to a martensitic type with type C_2 carbides. The table further indicates that one of the most effective ways of increasing the strength and toughness of the 12-16 per cent chromium-molybdenum irons is to increase their solidification rate by chill casting. In this case the chills were graphite molds.

The data in Table 9 further indicate that as the carbon content of the 12 to 16 per cent chromium-molybdenum irons is increased, a drop in strength and toughness occurs. Lowest values are obtained in high-carbon, sand-cast irons.

Mechanical Properties as Indicated by Field Experience. In actual applications, the properties most desired in white iron castings, in addition to abrasion resistance, are freedom from breakage and spalling in service. Freedom from breakage is obtained by providing the castings with adequate strength and toughness, together with relatively low values of residual tensile stress. Freedom from spalling under repeated impact involves more complex and more obscure requirements, and appears to be largely a function of composition, microstructure and design of the casting.

In grinding mill liners, wear shoes, mixing paddles and other relatively flat shapes, the martensitic irons are reported to be definitely tougher and less susceptible to breakage than the pearlitic white irons of roughly equivalent carbon content. Experience with the 12 to 30 per cent chromium irons indicates they are the toughest of the martensitic types.

High Residual Stresses

Castings which tend to develop high residual stresses in their structure due to their shape, present a more complex problem insofar as resistance to breakage or cracking in concerned. Under these circumstances, it is difficult to predict the type of white iron which will be most resistant to cracking during production or use of the castings.

The toughness of grinding balls presents an interesting problem in the selection of a suitable material for service under conditions where appreciable impact occurs. Here the pearlitic white irons have been found to be more resistant to breakage or

TABLE 8 — TENSILE PROPERTIES OF TWO TYPES OF MARTENSITIC WHITE IRON[19]

Nominal Composition	Carbide Type C_1	Carbide Type C_2
Carbon, %	3.4	2.6
Chromium, %	2.0	26.0
Nickel, %	4.0	—
Condition	**stress relieved**	**as-cast**
Tensile strength, psi	30/60,000*	85,000
Yield strength, psi	—	80,000
Total elongation (elastic+plastic), %	0.10 to 0.35	0.20 to 0.40
Elastic modulus, psi × 10⁶	24 to 26	31.5
Brinell hardness	500 to 700	450 to 650

*The higher strengths were obtained with faster cooling rates.

TABLE 9 — TRANSVERSE STRENGTHS AND RELATIVE TOUGHNESS OF VARIOUS PEARLITIC AND MARTENSITIC WHITE IRONS*

Item	Type of Iron	Transverse Strength, lb	Deflection in.	Relative Toughness**
1	Pearlitic, 1 to 2% Cr, 3.2 to 3.5% C. Sand cast.	1400-1800	0.080-0.092	112-165
2	Martensitic 12-16% Cr, 2.0-4.0% Mo, 2.8-3.4% C. Sand cast.	2235-3015	0.125-0.143	278-432
3	Martensitic 12-16% Cr, 2.5-3.0% Mo, 3.5-4.1% C. Sand cast.	1760-2200	0.079-0.110	139-242
4	Martensitic 12-16% Cr, 1.5-3.0% Mo, 3.2-3.4% C. Chill cast.	4360-5060	0.202-0.256	880-1296
5	Martensitic 12-16% Cr, 2.5-3.0% Mo, 3.5-4.1% C. Chill cast.	2800-3470	0.140-0.148	392-486

*Obtained from 1.2-in. diameter bars on 18-in. span.
**Relative toughness here is expressed as the product of breaking load times deflection.

spalling than nickel-chromium martensitic white irons with type C_1 carbides and a high retained austenite content. Studies made on this problem by the authors and by others indicate that these martensitic iron balls are more resistant to breakage on a single blow impact test, but when these same balls are run in a ball mill the repeated impacts, and resultant work hardening of the entire surface of each ball, causes some of the retained austenite at and near the wearing surface to transform to martensite.

This in turn induces high compressive stresses in this spherical surface, since the tranformed austenite, with its greater specific volume, is restrained from expanding. To balance these high compressive stresses, high tri-axial tensile stresses develop in the interior of the ball, which may eventually cause rupture or severe spalling in service. A similar effect has also been experienced with martensitic steel balls when they contain a high proportion of metastable austenite.[9]

The unfavorable stress effects from metastable austenite in martensitic white iron grinding balls can be reduced by several means. These generally involve a reduction in the amount of retained austenite or in the austenite-stabilizing elements. These methods will be discussed in greater detail in later sections of this paper.

WHITE IRON MARTENSITE STRUCTURE DEVELOPMENT

Pearlite Suppression

Methods of Test. For the fabrication of martensitic iron castings, it is necessary to use balanced alloy compositions capable of suppressing pearlite in the structures of various size sections during continuous cooling after solidification. Of the many methods of determining the effects of various alloy additions on pearlite suppression in white irons, the Time-Temperature-Transformation diagrams, drawn from isothermal transformation data by Rote,[20] appear to most closely simulate actual casting practice, because, in this work, castings after shake-out were continuously air cooled to the transformation temperature. The T-T-T diagram, as proposed by Rote, appears to have been constructed to serve as a guide for the fabrication of large-section castings.

For a guide to the study of alloy additions to white iron for small size castings (those which will cool to 800 F in less than 30 min), a modified end-quench hardenability test was adopted. The end-quench hardenability test has many advantages. This test has been universally accepted for steels for its ease of specimen fabrication, economy of material and the simplicity and reproducibility of testing.

The end-quench test modified for white irons consists of casting a flanged specimen 1.2 in. diameter by 3½-in. long in a sand or chill-type mold. The specimen after shake-out at about 1800 F is transferred to a holding furnace at 1700-1800 F for temperature equalization, prior to end-quenching in a modified Jominy fixture. Although the transfer of the casting to a holding furnace for temperature equalization does not necessarily represent the continuous cooling encountered in actual foundry practice the test procedure is consistent, and the effect on transformation during end-quenching would be expected to be reproducible.

Hardness measurements are obtained 0.100 in. below the cast surface along the length of the specimen. Due to the large amount of carbide phase in a 3.5 per cent carbon white iron, the transformation of austenite to pearlite may be insensitive to hardness measurement. In addition to the influence of carbide on the hardness, the proportion of austenite in the martensite-austenite-carbide aggregate will also affect the hardness. Hardness values obtained in 3.5 per cent carbon martensitic irons ranged from 52 to 70 Rockwell C. A typical pearlitic white iron of the same carbon content had a hardness of about 56 Rockwell C.

To supplement hardness measurements, the distance from the quenched end to the point at which pearlite first appears is measured by metallographic examination of the surface on which hardness impressions were obtained. This location is called the pearlite point. The location of complete transformation to pearlite often occurs at cooling rates lower than obtainable with the end-quench bar.

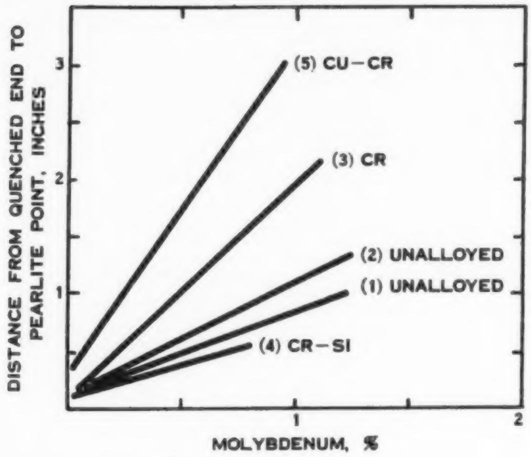
Carbon and Alloying Elements Effect. The effects of various alloy additions on the location of the pearlite point in a number of different investigations of white irons at the authors' laboratory are summarized in Figs. 11-14. In the various base compositions tested, nickel, molybdenum, manganese and copper additions effectively delayed the appearance of pearlite in the structure, as shown in Figs. 11 and 12. Chromium contents up to 13 per cent had relatively little effect on the appearance of pearlite at a constant carbon content, as shown in Fig. 13.

Silicon additions to the base compositions produced a negative effect and accelerated the appearance of pearlite, as shown in Fig. 14. Although the relative effectiveness of various alloying elements in suppressing pearlite is demonstrated in Figs. 11-14, the efficiency of each addition is strongly dependent on the base alloy combination, and to some extent on the carbon content of the austenite resulting from variations in solidification rate.

The effects of carbon and molybdenum additions, and the solidification rate on pearlite suppression of high chromium irons, are shown in Figs. 15-17. The data presented in Fig. 15 indicate that carbon additions affect the appearance of pearlite in a manner similar to the negative effect of silicon additions, shown in Fig. 14. Consideration of Fig. 16 suggests that the effectiveness of molybdenum additions is greater at low carbon levels. The data in Fig. 17 indicate that increases in solidification rate are more effective at low carbon levels.

Carbon and Solidification Rate Effect on Hardness

An example of the influence of carbon and solidification rate on the hardness of high chromium irons is given in Fig. 18. For the compositions shown in Fig. 18, it is quite probable that some correlation exists between hardness and abrasion resistance, since the hardness is primarily related to the quantity and



Base Composition, %

	C	Cr	Si	Cu	
(1)	3.5	—	0.32	—	sand cast
(2)	3.5	—	0.32	—	chill cast
(3)	3.6	5.0	0.50	—	sand cast
(4)	3.7	4.8	1.50	—	sand cast
(5)	3.4	0.9	0.19	2.1	chill cast

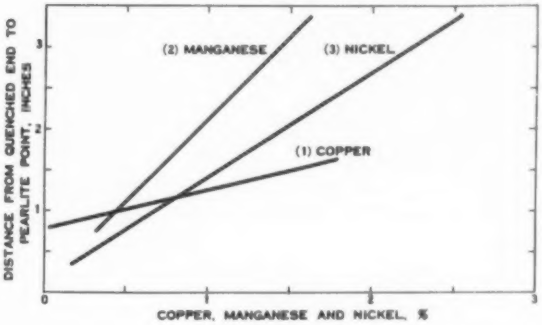
NOTE: 1.2 in. dia. specimens held at 1700-1800 F after casting prior to end quenching.

Fig. 11 — Molybdenum effect on hardenability (pearlite suppression) of low alloy white irons.

distribution of the carbide. However, it is apparent from the graph that an increase in hardness with increasing carbon content is nonlinear. The higher hardness values are related to an increase in the amount of martensite in the matrix, as well as an increase in the amount of carbide phase present.

It is apparent that hardness is also affected significantly by solidification rate. It is possible to achieve the same hardness at a lower carbon content by increasing solidification rate in these high chromium irons.

It has been observed by others that hardness of the nickel-chromium type martensitic white irons with

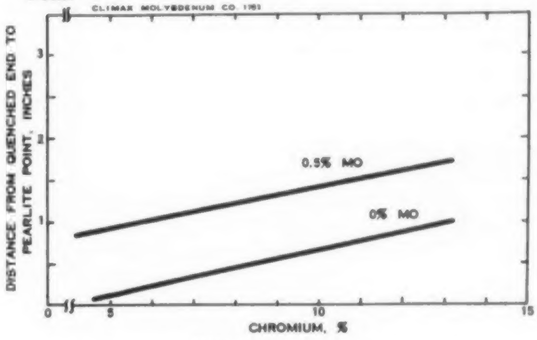


Base Composition, %

	C	Mn	Cr	Cu	Mo
(1)	3.5	0.6	—	—	1.0
(2)	3.4	0.6	—	1.5	1.0
(3)	3.4	0.7	1.5	—	—

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after sand casting prior to end quenching.

Fig. 12 — Copper, manganese and nickel effect on hardenability (pearlite suppression) of low alloy white irons.

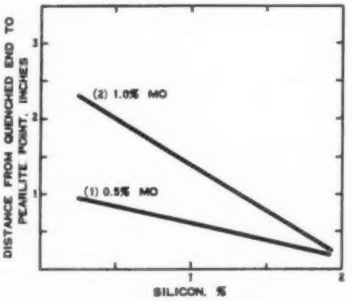


Base Composition, %

C	Mn	Mo
3.6	0.7	—
3.6	0.7	0.5

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after sand casting prior to end quenching.

Fig. 13 — Chromium effect on hardenability (pearlite suppression) of alloyed white irons.

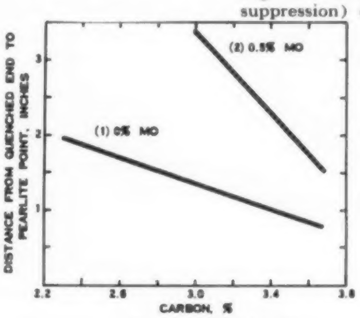


Base Composition, %

	C	Mn	Cr	Mo
(1)	3.6	0.7	5.0	0.5
(2)	3.6	0.7	5.0	1.0

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after sand casting prior to end quenching.

Fig. 14 — Silicon effect on hardenability (pearlite suppression) of low alloy white irons.

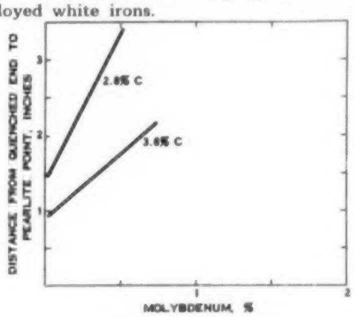


Base Composition, %

	Si	Mn	Cr	Mo
(1)	0.6	0.7	12.5	—
(2)	0.6	0.7	12.5	0.5

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after sand casting prior to end quenching.

Fig. 15 — Carbon effect on hardenability (pearlite suppression) of high chromium white irons.

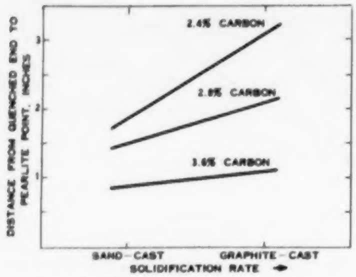


Base Composition, %

Mn	Si	Cr
0.74	0.6	12.4

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after sand casting prior to end quenching.

Fig. 16 — Molybdenum effect on hardenability (pearlite suppression) of high chromium irons.

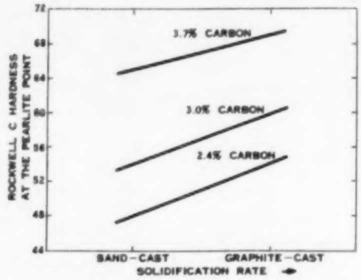


Base Composition, %

Mn	Si	Cr
0.74	0.6	12.4

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after casting prior to end quenching.

Fig. 17 — Solidification rate effect on the hardenability (pearlite suppression) of high chromium irons at three carbon levels.

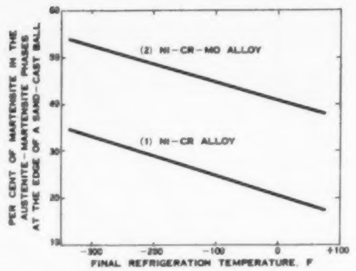


Base Composition, %

Mn	Si	Cr	Mo
0.74	0.6	12.4	0.5

NOTE: 1.2 in. dia. specimens held at 1700-1800 F after casting prior to end quenching.

Fig. 18 — Solidification rate effect on the hardness of high chromium irons at three carbon levels.



Base Composition, %

	C	Si	Mn	Ni	Cr	Mo
(1)	3.4	0.4	0.65	3.0	2.2	—
(2)	3.4	0.4	0.70	0.21	2.0	0.44

NOTE: 2 in. dia. balls were air cooled after sand casting and held at final refrigeration temperature for 30 min. Martensite determined by x-ray diffraction.

Fig. 19 — Final refrigeration temperature effect on amount of martensite in two low alloy white irons.

type C_1 carbides also generally increases with increasing carbon content, which is similar to the effect noted in Fig. 18.

Arrested Cooling Effect

Reduction of the carbon content of the austenite phase by arrested cooling, following solidification, offers a method of increasing the pearlite-suppressing power of nickel-chromium and nickel-chromium-molybdenum irons with type C_1 carbides. The work by Rote clearly shows the advantages of this treatment. This arrested cooling treatment shifted the pearlite transformation of the T-T-T diagram to the right, delaying the appearance of pearlite in the structure.

This may be accomplished in commercial practice by transferring the castings, after solidification, to a preheated furnace at a temperature of about 1700 F. Following this, the castings are cooled to room temperature. A somewhat similar effect can be achieved by burying the castings together after solidification.

Arrested cooling is quite effective in reducing retained austenite, and in suppressing pearlite in high chromium irons containing type C_2 carbides. In these irons, the arrested cooling tends to produce a dispersion of spheroidized carbides in the austenite, lowering the carbon content of the austenite. On subsequent cooling of the lower carbon austenite, pearlite transformation is delayed even in the presence of nucleating carbides.

Retained Austenite Control

Practically all martensitic white irons contain significant amounts of retained austenite, which has an influence both on abrasion resistance and mechanical properties. Its influence upon these properties is rather complex, and in some cases obscure.

Insofar as its effects on mechanical properties are concerned, retained austenite always tends to lower the hardness of martensitic white irons. At the same time it may increase their toughness as measured in a tensile or transverse test, or by single-blow impact. Where repeated impact occurs over a wearing surface, as in the case of grinding balls, the retained austenite may produce an apparent brittleness, due to buildup of residual stresses under this wearing surface. Under these circumstances it is desirable to reduce the amount of retained austenite.

When martensitic white iron castings must be cleaned or finished by grinding before service, the presence of high retained austenite tends to produce hair-line cracks or heat checks on the finished surfaces.

Retained austenite in martensitic white irons can be reduced by various means. One method is to refrigerate the castings at subzero temperatures. This should be followed by a stress-relieving treatment at about 400 F. Figure 19 shows the effect of refrigeration on the martensite content of a nickel-chromium and a nickel-chromium-molybdenum iron. A second method involves tempering at 500 to 550 F, which transforms some of the retained austenite, probably to low-temperature bainite. A third method is to arrest cooling after solidification, as described in the previous section.

A fourth method is to use selectively those alloying elements which suppress pearlite, but have little tendency to stabilize austenite or lower its M_s temperature. This fourth method may, if desired, be combined with one or more of the other three.

Retained austenite can also be reduced or controlled by reheating the castings to suitable austenitizing temperatures, followed by mild quenching. This procedure is well adapted to the 12 to 30 per cent chromium irons, since their type C_2 carbides are discontinuous and permit the use of heat treating procedures similar to those used on tool steels. This reheating and quenching procedure also provides a convenient means of producing a martensitic structure in those large or heavy section castings, which normally have a pearlitic structure after slow cooling in their sand molds.

The influence of retained austenite on abrasion re-

sistance, in the absence of spalling or breakage, appears to be largely dependent upon the composition of the austenite. This effect of composition on the abrasion resistance of a number of martensitic white irons and high carbon steels has been studied and reported in a previous paper by one of the authors.[9] These invesitgations have indicated that when austenite is retained by increasing its carbon or chromium content, an improvement in abrasion resistance is produced. On the other hand, when austenite is retained by increasing its manganese or nickel contents, a lowering in abrasion resistance occurs.

This effect for varying nickel contents in martensitic white iron grinding balls is indicated in Fig. 20. It appears desirable, therefore, in the interest of obtaining optimum abrasion resistance, to hold the manganese and nickel contents to the minimum required to suppress pearlite in their structure. This can be accomplished by the use of balanced alloy combinations, which will be discussed in the next section.

Refrigeration of nickel-chromium and nickel-chromium-molybdenum irons to reduce their austenite content has improved their wear resistance when they were tested as grinding balls in high stress abrasion. This is indicated by the nickel-chromium iron in Fig. 20, and has been further confirmed by similar investigations on nickel-chromium-molybdenum irons. Presumably this refrigeration treatment would be helpful in providing added abrasion resistance in other types of abrasive wear.

Tempering treatments at 500 to 550 F have been investigated in a few tests, which indicated that a small loss in abrasion resistance was produced by this treatment on grinding balls. This may be over-balanced by the increased resistance to spalling and breakage which the tempering treatment provides. In general, however, a refrigeration plus stress-relief treatment appears to be preferable to the tempering treatment, both from the standpoint of abrasion resistance and resistance to spalling.

The effects on abrasion resistance which are produced by arrested cooling treatments have not been investigated by the authors.

The reduction of retained austenite in nickel-chromium irons by the use of a lower nickel content, combined with a molybdenum addition for pearlite suppression, provides a means of improving the abrasion resistance of these irons. This is indicated by a comparison of items 3 and 4 in Table 5. A further improvement in the abrasion resistance of these two irons was obtained by refrigeration at minus 70 F.

BALANCED COMPOSITIONS FOR MARTENSITIC WHITE IRONS

On the basis of present knowledge, the formulation of balanced compositions for martensitic white iron castings should have the following major objectives:

1) A sufficient alloy content to suppress the formation of pearlite in a given casting section size and cooling rate.
2) A sufficient quantity of carbide-stabilizing elements to ensure freedom from graphite in the structure.
3) A high carbon content where optimum abrasion resistance is the controlling factor, or a low carbon content where maximum toughness is necessary.
4) A low silicon content to reduce the tendency for graphite formation and/or pearlite formation.
5) Adjustment of alloy combinations for control of retained austenite to suit the conditions under which the castings are produced and used in service.
6) Addition of alloying elements to increase the hardness of the carbide phase.
7) Addition of alloying elements to increase the toughness of carbides by modifying the composition, shape and distribution of the carbide phase.

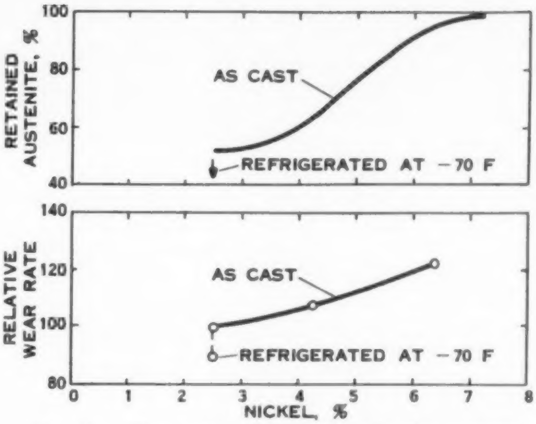


Fig. 20 — Wear rates and retained austenite contents (in martensite-austenite phases) for chill cast nickel-chromium martensitic white iron balls grinding river sand in a 3-ft ball mill. Wear rates are relative to 100 for 0.80 per cent carbon martensitic steel.

All of the foregoing objectives must, of course, be balanced against their cost in relation to the benefits obtained. For instance, a high-chromium molybdenum iron with type C_2 carbides may provide best abrasion resistance in a specific application, but a nickel-chromium-molybdenum iron with type C_1 carbides may provide better economy because of its normally lower first cost.

The foregoing objectives have resulted in the development of two major classifications of martensitic white iron. One depends largely upon the use of nickel, and, more recently, nickel plus molybdenum for pearlite suppression. Chromium, with a low silicon content, is used to suppress graphitization, and also assists in pearlite suppression. The type C_1 carbides are obtained in this type of iron.

The other major classification of martensitic white irons depends on the use of chromium contents in excess of 10 per cent to produce type C_2 carbides in the structure. The type C_2 carbides are harder than the type C_1. They are discontinuous and more favorably dispersed, and tend to have a fine particle size. Complete suppression of graphite in these high chromium irons is obtained due to the chromium content, while pearlite is suppressed by the use of

molybdenum in combination with the chromium. Retention of good mechanical properties with high carbon contents, and consequent optimum abrasion resistance, are obtainable when the chromium content of the irons is held within a range of about 12 to 16 per cent.

The recommendation of specific compositions for each of the two major types of martensitic white irons is beyond the scope of this paper. While the desirable limits of their composition ranges are believed to be fairly closely indicated by the data which have been presented, the most desirable or economical compositions for specific conditions of production and use will vary to some extent. A number of specific compositions for various applications have been indicated in the tables.

SUMMARY AND CONCLUSIONS

1) Two basic types of martensitic white irons are described and defined. One contains a structure of type C_1 carbides (Fe_3C) and austenite, or one of its low temperature transformation products. The other contains type C_2 carbides [$(Cr,Fe)_7C_3$)] and austenite, or one of its low temperature transformation products. Representative microstructures for each type of iron are given and compared to corresponding pearlitic white irons.
2) Both types of martensitic white irons have shown substantially better abrasion resistance than pearlitic white irons in comparative tests. Where comparisons were available, the martensitic white irons with type C_2 carbides were superior to martensitic white irons with type C_1 carbides.
3) The strength and toughness of martensitic white irons are generally superior to those of pearlitic white irons. The martensitic irons with type C_2 carbides showed the best values of strength and toughness.
4) The effects of the commonly used alloying elements, and of carbon and silicon, on the suppression of pearlite in white irons are presented and discussed. Molybdenum, manganese, nickel, copper and chromium were shown to be effective in retarding pearlite formation. Carbon and silicon were shown to accelerate pearlite formation.
5) The effects of solidification rates on mechanical properties and pearlite suppression are presented and discussed. Chill casting was shown to enhance both mechanical properties and pearlite suppression.
6) Heat treatment of martensitic white irons is discussed. Arrested cooling in the range 1400-2000 F is effective in suppressing pearlite. The white irons with type C_2 carbides respond well to reheat treatments, which promote martensite formation.
7) The influence of retained austenite, and methods used for its control, are presented and discussed. Both mechanical and abrasion resistance are influenced by the quantity and composition of the retained austenite.
8) Balanced compositions for the development of optimum properties in martensitic irons are discussed.

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More than Half of Chapters Contribute AFS Presidents Since Formation 1896

■ More than half of the 47 AFS Chapters have contributed Presidents to the Society. Fifty-seven Presidents from 26 Chapters have served the Society since 1896.

Three Chapters, Chicago, Northeastern Ohio and Pittsburgh, each are represented by six Presidents. Detroit and Philadelphia both have five representatives.

The AFS Presidents and their Chapter areas:

BIRMINGHAM – L. N. Shannon (1940-41); L. H. Durdin (1958-59).
CANTON – L. W. Olson (1924-25); J. L. Wick, Jr. (1936-37).
CENTRAL ILLINOIS – F. W. Shipley (1956-57).
CENTRAL INDIANA – I. R. Wagner (1952-53).
CENTRAL MICHIGAN – C. L. Carter (1953-54).
CENTRAL OHIO – J. G. Sadlier (1901-02).
CHESAPEAKE – E. W. Horlebein (1949-50).
CINCINNATI – C. S. Bell (1898-99).
CHICAGO – W. A. Jones (1900-01); C. J. Wolff (1904-05); S. T. Johnston (1928-29); T. S. Hammond (1932-33); H. S. Simpson (1941-42); B. L. Simpson (1955-56).
CONNECTICUT – W. R. Bean (1920-1922); H. S. Washburn (1939-40).
DETROIT – A. T. Waterfall (1909-10); S. W. Utley (1926-1928); Fred Erb (1929-30); F. J. Walls (1945-46); H. W. Dietert (1957-58).
NEW ENGLAND – A. W. Walker 1902-03); A. B. Root, Jr. (1925-26); E. H. Ballard (1931-32).
NORTHEASTERN OHIO – B. D. Fuller (1917-18); A. O. Backert (1918-19); D. M. Avey (1934-1936); W. L. Woody (1950-51); W. L. Seelbach (1951-52); F. J. Dost (1954-55).
NORTHERN ILLINOIS-SOUTHERN WISCONSIN – D. P. Forbes (1942-43).
NORTHWESTERN PENNSYLVANIA – Willis Brown (1903-04); T. D. West (1905-06).
ONTARIO – L. L. Anthes (1908-09).
PHILADELPHIA – F. Schumann (1896-1898); S. G. Flagg, Jr. (1907-08); Dr. G. H. Clamer (1923-24); Marshall Post (1938-39); L. C. Wilson (1943-44).
PIEDMONT – Max Kuniansky (1947-48).
PITTSBURGH – J. S. Seaman (1899-1900); W. H. McFadden (1906-07); J. T. Speer (1910-1912); C. S. Koch (1919-20); F. J. Lanahan (1933-34); W. B. Wallis (1948-49).
QUAD CITY – H. Bornstein (1937-38).
ST. LOUIS – R. A. Bull (1914-1916); J. P. Pero (1916-17).
TENNESSEE – A. E. Howell (1913-14).
TWIN CITY – S. V. Wood (1946-47).
WESTERN MICHIGAN – R. J. Teetor (1944-45).
WESTERN NEW YORK – H. D. Miles (1912-13); N. D. K. Patch (1930-31).
WISCONSIN – C. R. Messinger (1922-23).

Film Explains Foundry Field

■ A better understanding of the casting industry, its scope, training needs, stability and opportunities possible, is presented in a 22-min, sound film, *Cast Metals and You.*

The film, originally silent and titled *Education and Our Industry's Survival,* was presented by the Society by Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago. A sound track, title change and the reshooting of some scenes were recommended by the Education Division Sub-Committee on Film Evaluation and Recommendations.

Objectives of the film are to: 1) show the scope and stability of the castings industry; 2) show the need for training; 3) awaken youth to available job opportunities; 4) acquaint the general public with the industry; 5) acquaint youth and parents with basic training opportunities available.

To find the reaction of various groups, the film was shown to representative groups of juveniles and mixed parents. More than 250 students viewed the film in addition to teachers and P.T.A. parents.

In general all persons viewing the film felt it was well planned and presented and that it could be used for a junior high or early high school guidance film. It was felt that it would be of great value for the orientation of all industrial apprentices and trainees and could also be used by personnel managers in explaining the value and need for an organized foundry training program.

Members of the sub-committee are: Chairman I. H. Dennen, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago; Prof. R. W. Schroeder, University of Illinois, Navy Pier, Chicago; R. A. Oster, Beloit Vocational & Adult School, Beloit, Wis.; A. C. Smith, American Steel Foundries, Chicago.

AFS 1896

news and views

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Board Authorizes Second-Stage Development of Training Center

Acceptance of Trustee Recommendations Points Way Toward Completion of "America's Foundry Technical Center"

■ The Board of Directors of AFS voted unanimously to finalize plans and detailed specifications for a proposed Foundry Training Center building, at a special Board meeting held Feb. 10 at the Society's national offices in Des Plaines, Ill. In doing so, the Board accepted recommendations of the Training and Research Institute trustees, reported in the February issue of MODERN CASTINGS, that the project be completed "at the earliest possible date."

Attending the meeting, called by President L. H. Durdin exclusively to consider all aspects of the overall T&RI program, were 20 of the 24 incumbent officers and directors of the Society, and seven of eight officer and director nominees. The latter participated in all discussions as observers, without vote on the final motion. The trustees' recommendation was presented in person by H. Bornstein, chairman of trustees.

Reviews Program

Urging favorable action by the AFS Board, Bornstein reviewed organization of the Institute in December 1956, at which time the trustees requested that approval of the proposed training building be deferred pending more concrete evidence of its actual need. Enthusiastic reactions to the eight trial courses presented in 1957 and 13 in 1958, he said, had convinced the trustees that the Institute's training program could not be fully progressed without more adequate facilities.

He pointed out that students attending the courses during the past two years came from 32 states, two Canadian provinces and Mexico, and traveled an average distance of 722 miles to do so. Practically all, Bornstein reported, expressed strong appreciation for the material presented and indicated desire to attend further courses.

In recommending for the second time that the training building should now be built, the chairman likened the project to date to the steps nec-

AFS President L. H. Durdin

essary in manufacturing a new product. "In 1957," he said, "we had our experimental program of courses. This was followed in 1958 by a pilot plant operation of broadened courses and field services, and we are continuing pilot operations in 1959. The T&RI Trustees now say to you: 'We are ready for production, provided you furnish us with the necessary facilities.' Gentlemen, it is your next move."

The T&RI Chairman emphasized that the proposed building, even if approved at this time, probably could not be available for training courses before the fall of 1961. He presented a "construction timetable" representing estimates made by the trustees, as follows:

Estimated Timetable

Feb., 1959—Board authorization to proceed.

March, 1959—Final approval of design and plans, selection of official architect.

March, 1959—Commence final drawings, detailed specifications.

July, 1959—Approve specifications, select contractors for bidding.

Aug., 1959—Submit plans, specifications for general contract bids.

Nov., 1959—Deadline for return of general contract bids.

Nov., 1959—Executive Comm. approve low bid for construction.

Dec., 1959—Finance Comm. arrange financing.

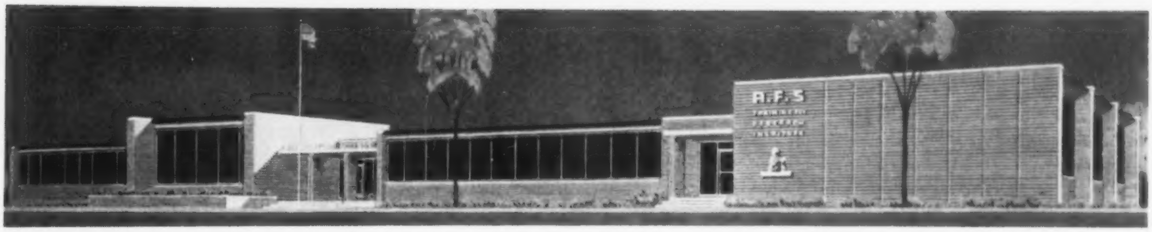
April, 1960—Commence building construction.

Oct., 1961—Completion of building.

Nov., 1961—First T&RI courses in new building.

Discussion of the Institute's training program gave special attention to: centralized location; accessibility via Chicago's new expressways and relocation of Chicago's airport at O'Hare Field; the training center "potential," projected over a 25-year period in terms of increased demand

AFS Board of Directors show at Central Office in Des Plaines, Ill. The Board met Feb. 10 in a special meeting to discuss the Training & Research Institute program. T&RI Trustee Chairman Hyman Bornstein presented the Trustees recommendations and reviewed the T&RI program. Courses have been conducted both in the United States and Canada. Chapters have co-sponsored courses with T&RI in several cities.



An artist's conception of proposed T&RI Training Center adjoining present AFS Headquarters which is shown to left of flag pole. Pictured below are T&RI Trustee Chairman H. Bornstein, T&RI Director S. C. Massari and Trustee I. R. Wagner. Wagner, who served as a trustee 1957-1959 has been elected to serve a four-year term. Other trustees are H. W. Dietert, L. H. Durdin, C. E. Nelson, R. A. Oster and B. C. Yearley. Wm. W. Maloney serves as Secretary and E. R. May as Treasurer.

H. Bornstein
Trustee Chairman

Institute Director
S. C. Massari

I. R. Wagner
T&RI Trustee

for qualified personnel; estimated 30 course weeks per year covering a broad range of subjects; total cost of building and equipment, presently estimated at $500,000.

Form Building Committee

The discussion culminated in a motion authorizing the Society's officers to proceed with construction of the training center building "in accordance with the estimated construction timetable, subject to approval of general contract bids by the Executive Committee of the Board."

A Building Committee of specialists, appointed by the AFS President, will develop and approve plans and specifications in cooperation with the Institute's Director.

When the present AFS Headquarters building was announced in 1950, the industry contributed nearly $227,000 to make possible this first step in developing "America's Foundry Technical Center." Similar structures housing activities of European foundry technical groups now exist in England, France, Belgium, Germany, Spain and Italy. The new T&RI Foundry Training building will complete the Foundry Technical Center envisioned years ago and enable the American castings industry to keep pace with foundry progress around the world.

Elected Director

D. L. Colwell, Apex Smelting Co., Cleveland, was elected Director at large by the AFS Board of Directors at its February meeting. Colwell is Chairman of the AFS Die Casting & Permanent Mold Division.

T&RI Opens 1959 Program with 2-Day Courses at Birmingham

■ *Gating & Risering of Castings*, first cooperative course in the AFS Training & Research Institute 1959 program, was presented Feb. 23-25 at Birmingham, Ala. The course, held at the Dinkler-Tutwiler Hotel, was jointly sponsored by the AFS Birmingham Chapter and T&RI.

Instructors were Charles Locke, Crucible Steel Castings Co., Cleveland; Karl G. Presser, Buckeye Foundry Co., Cincinnati; R. A. Colton, American Smelting & Refining Co., Houston, Texas; S. C. Massari, AFS Technical Director and R. E. Betterley, T&RI Training Supervisor.

Three films were used to present the latest in research work. They were the AFS research project films "Effect of Horizontal Gating Design on Casting Quality" and "A Study of Vertical Gating Design;" and "Metal Flow in Molds" by Institute of British Foundrymen.

Included in the course were basic fundamentals, flow patterns in gating systems and mold cavities, gating and risering of ferrous castings and in addition, gating and risering of non-ferrous alloys.

Wisconsin Regional Conference Stresses Ways to Cut . .

■ Incorporating the latest methods and techniques into foundry production was stressed at the 22d annual Wisconsin Regional Foundry Conference. Speakers emphasized how costs can be reduced and castings improved both through new concepts and application of basic fundamentals.

Considerable interest was expressed in General Motors Corp. development of an as-cast malleable iron with superior mechanical properties and a high elastic modulus approaching that of steel. The alloy, known as Centra-Steel, does not require extensive heat treatment, explosive or costly addition agents, injection apparatus or low maximum sulfur content.

The conference, sponsored by the AFS Wisconsin Chapter in cooperation with the University of Wisconsin, was held Feb. 12-13 at the Schroeder Hotel, Milwaukee. Lawrence J. Andres, Lawran Foundry Co., Milwaukee, served as general conference chairman. Clarence A. Gehrman, Sterling Wheelbarrow Co., Milwaukee, and Prof. P. C. Rosenthal, University of Wisconsin, Madison, Wis., served as co-chairmen.

Each of the chapter's five divisions presented four technical sessions during the two-day conference.

In opening the conference, AFS President L. H. Durdin and Kurt F. Wendt, dean, College of Engineering, University of Wisconsin, both examined the relationship of education and industry.

Durdin urged a united, industry-wide research program rather than efforts by individual foundries. He emphasized the small amount spent by foundries on research activities compared to other metal industries. And he urged support of the proposed AFS Training & Research Institute Center to be constructed adjoining the AFS Headquarters in Des Plaines, Ill.

Dean Wendt said that the industry must meet challenges from other fabrication methods through intensive self-study, company research, cooperative research and a continuous drive to obtain the best possible talent. He emphasized that the industry must make students conscious of the advancement possibilities throughout the metalscasting field.

Luncheon and dinner speakers included Larry Clark, Wisconsin Lincoln Sesquicentennial Committee, who presented a film, "The Face of Lincoln;" Col. Arnold M. Maahs, U. S. Army Active Reserve, who discussed "The Mighty St. Lawrence–Seaway to the World;" and John W. Mullen, farm director, Milwaukee Braves Baseball Club, who spoke on "Outlook for the Milwaukee Braves."

The technical program was opened by AFS Director of Safety, Hygiene and Air Pollution Control, H. J. Weber, who discussed principles of controlling noise such as by substitution of less noisy operations; isolation of noisy operations; control of noise by distance, enclosure, insulators and acoustical tile. Following this, he gave practical applications of these principles suitable for us in foundry operations.

Steel Sessions

Sands with a broad distribution are increasing in use compared to sands of narrow distribution and sands of narrow distribution plus silica flour, reported V. M. Rowell, Harry W. Dietert Co., Detroit. Advantages appear to be high density, dry compressive strength, hot strength, glazing ability, green compressive strenth and green tensile strength. Broad distribution sands are also lowest in permeability, rate of expansion as well as superior in spalling resistance.

Roof life in electric furnaces may be extended through correct design and utilization of proper brick, said C. E. Grigsby, General Refractories Co., Philadelphia. In many cases additional life may be obtained by using mortar in joints and insulating around the annular section ring; use of steel plate cast into brick; and often brick of smaller size with center ramming gives longer life than large sized interlocked brick.

Designing castings to develop highest service strength must take into consideration that castings excel in their ability to uniformly distribute the load, rather than because of their tensile strength, emphasized J. B. Caine, consultant, Cincinnati. Foundrymen must be prepared to assist designers, particularly in the design properties of junctions, sections and connecting members.

Shell molds and cores have a place in the steel castings industry, but the success of the application depends greatly on the customer's standards for his castings. This was one conclusion reached by a panel of foundrymen who have found limitations in the production of steel castings in shell, and who have investigated corrective measures to overcome these limitations. Panel members were: J. R. Vinette, Evinrude Motors Div., Outboard Marine Co., E. G. Tetzlaff, Pelton Steel Casting Co.; D. J. Koch, Sivyer Steel Casting Co.; and J. A. Behring, University of Wisconsin.

AFS President L. H. Durdin speaking before **Wisconsin Regional Foundry Conference.** Durdin emphasized need for industry-wide research.

Gray Iron Sessions

Required carbon analysis of gray iron does not limit the amount of steel scrap used in the charge since there are many ways of speeding carbon absorption by iron in the cupola, said N. P. Lillybeck, Brillion Iron Works, Inc., Brillion, Wis. Advantages which may be gained by using high steel charges include low phosporous content, greater freedom from tramp and residual elements, increased pearlite stability, increased response to hardening agents and high impact strength.

Solidification and risering of gray iron castings were explained by M. C. Flemings, Massachusetts Institute of Technology, Cambridge, Mass. The natural reduction in volume accompanying the cooling of gray iron from the liquid to the solid depends upon metal chemistry. However, the size and location of voids are also dependent on factors influencing the movement of the casting surface.

Ductile iron quality depends upon three factors: base iron composition, magnesium content level and final inoculations, C. K. Donoho, American Cast Iron Pipe Co., Birmingham, Ala., told foundrymen. Donoho illustrated the determination of optimum magnesium content for several experimental heats.

. . Casting Costs While Improving Quality

C. K. Donoho addressing foundrymen at **Wisconsin Regional Foundry Conference** on production of ductile iron.

Hot-blast improves cupola operation by increasing temperature in the melt zone, resulting in hotter iron, lower silicon and manganese loss, more fluid slag and cleaner melting and less bridging, explained D. E. Krause, Gray Iron Institute, Columbus, Ohio. Technical advantages include melt rate, high carbon pick-up and lower cost charge materials, increased fast recovery after shut-down.

Malleable Sessions

Annealing of malleable iron in a nitrogen atmosphere furnace capable of close control of temperature gradient was reviewed by L. Emery, Marion Malleable Iron Works, Marion, Ind. The electrically heated combination ferritic and pearlitic iron oven anneals 1000 tons of castings during a 40-hour cycle. With the aid of an automatically operated by-pass between the temperature zone and cooling zone it is possible to produce all S.A.E. grades of pearlitic malleable iron within a narrow range of Brinell hardness.

Pinhole porosity in malleable iron was discussed by Clifford Sorenson, National Malleable & Steel Castings Co., Cicero, Ill. Various causes were advanced for the defect. Fireclay facings were advanced as a possible solution.

Water-cooled cupolas have the advantage of flexibility and control of the melt process, prolonged periods of melting operation and decreased costs for refractory maintenance, Walter Schwengel, Modern Equipment Co., Port Washington, Wis., told malleable foundrymen. He defined these cupolas as liningless, externally water-cooled shell with protruding water-cooled tuyeres and a neutral refractory in the well.

CentraSteel talk was authored by W. B. Larson, Carl Joseph, W. F. Webbere and Dr. R. F. Thomson, General Motors Corp., Detroit. Details appear at beginning of this article.

Pattern Sessions

Pattern and core box equipment for modern high production work was described as to design, construction and standardization by Joseph M. Kreiner, National Malleable & Steel Castings Co., Cleveland. These patterns, constructed on an interchangeable basis have the advantages of economy and flexibility.

Plastics offer the patternshop a new engineering material that through judicious application can decrease fabrication costs and create varied product areas with enhanced customer response, stated J. Bruce Ferguson, Allis-Chalmers Mfg. Co., Milwaukee. Ferguson outlined experience in plastics started by Allis-Chalmers in 1956. The project has now been expanded well beyond the pattern field.

Plaster patterns, used increasingly in the auto and aircraft industries, offer stability, economy in tooling, savings in time and increased adaptability. How to properly use plasters was explained by M. K. Young, U.S. Gypsum Co., Chicago, with the use of 100 slides.

Pattern life extension through the use of a hard rubber plastic for manufacturing patterns and a coating on aluminum core boxes were described by J. E. Olson, Dike-O-Seal, Inc., Chicago. The core box coating gives a very hard surface prolonging wear and allowing easier draw-out compared to untreated aluminum, said Olson.

Non-Ferrous Sessions

Aluminum castings can be made better but defects must be correctly identified before corrective steps are taken, warned Donald L. LaVelle, Federated Metals Div., American Smelting & Refining Co., South Plainfield, N.J. LaVelle listed various symptoms and their cures in aluminum practice.

Casting finish must be improved to satisfy customer demands, emphasized Clyde A. Sanders, American Colloid Co., Skokie, Ill. Improved surface finish, closer tolerances and better dimensions are directly related to molding sand properties and methods. Many things make for better casting finish and surface, but sand grain is the most important. Foundry progress can be advanced considerably by making the most of what we already have, but utilizing a finer base sand to give this finish.

Causes of scrap castings and possible remedies were suggested to non-ferrous foundrymen by Fred Riddell, H. Kramer & Co., Chicago, in an illustrated lecture. Specific castings were shown with recommendations made to improve them.

Riddell outlined how proper gating and risering procedures, chills and insulation could be used to overcome many problems plaguing non-ferrous foundrymen.

Shell cores should be introduced into the non-ferrous foundry on a strict cost basis, according to S. Denkinger, Shalco Corp. He noted that the installation of shell core equipment is advantageous if the plant lacks core oven capacity or floor space because of lesser capital investment. In addition, pattern equipment for shell cores is cheaper, he stated, than equipment normally used for oil-sand cores with driers.

CentraSteel paper authors: **W. B. Larson, Carl Joseph, W. F. Webbere** and **Dr. R. F. Thompson** of General Motors Corp. Paper was presented by Larson. **Photos by Bob De Broux**

L. H. Durdin

D. E. Chester

F. E. Frazier

Alert Foundrymen to New Advances . .

■ New developments in foundry practice, management and legislation were presented at the 27th Southeastern Regional Foundry Conference held Feb. 26-27 at the Tutwiler Hotel, Birmingham, Ala.

The conference was sponsored by the AFS Birmingham and Tennessee Chapters and the University of Alabama Student Chapter. M. D. Neptune, James B. Clow & Sons, Birmingham, Ala., served as general conference chairman and J. R. Cardwell, Stockham Valve & Fittings, Inc., Birmingham, Ala., was program chairman.

In addition to the technical sessions, the conference was addressed by AFS General Manager Wm. W. Maloney and Herbert E. Smith, Jr., Associated Industries of Alabama. AFS President L. H. Durdin spoke at the annual banquet with Warren Whitney, James B. Clow & Sons, serving as toastmaster.

Other high-lights included a ladies program and plant visitations.

Better Castings: More aluminum castings are rejected due to poor pouring practice than for any other reason, stated R. A. Colton, American Smelting & Refining Co., Houston, Texas. Pouring is more critical in aluminum alloys than in others because it readily forms a tough, thin oxide film which has a specific gravity close to that of molten aluminum.

Birmingham Chapter co-sponsored three-day T&RI course prior to the Southeastern Foundry Conference. Shown are **C. M. Adams, Jr.**, speaker at the conference and AFS Technical Director **S. C. Massari.**

Preventing Defects: Melt quality, gating, proper feeding and optimum pouring temperatures were advanced as the prerequisites to the prevention of non-ferrous casting defects by Ray Cochran, R. Lavin & Sons, Chicago.

Gas defects due to the absorption of hydrogen are the principal causes of poor melt quality in aluminum castings. Prevention of the absorption is the only solution to the problem.

"Insufficient research has been done on the gating and risering of brass and bronze castings," said Cochran who pointed out that most of the research has been done with steel and light alloys. Ideally the gating system should fill the mold without turbulence, prevent aspiration of air and gas, minimize erosion, trap out dross and promote directional solidification.

Cochran, in dealing with risering, explained that directional solidification depended upon size, shape and location. He explained the difference in solidification between pure metals, short freezing range alloys and long freezing range alloys.

Direct Reduction: Foundries melting 100 tons or more of iron daily may have an opportunity to reduce their cost of iron and their dependence on outside sources for pig iron and scrap through the direct reduction of iron ore. Details on the process were outlined by H. W. Lownie, Jr., Battelle Memorial Institute, Columbus, Ohio.

Interest in the process has been stimulated by the diminishing supply of good coking coals and iron ores. Thirty-seven companies are now participating in the research at Battelle.

Currently it is estimated that the cost of molten metal in the ladle runs between \$55-\$110 per ton using conventional cupola methods.

Estimates on a \$2,500,000 pre-reduction and smelting plant with a 100-ton daily capacity, place the cost of molten metal at \$61 per ton. A \$6,000,000, 400-ton daily capacity installation would produce molten metal for about \$47 per ton.

Southeastern Regional General Conference Chairman **M. D. Neptune** addresses banquet audience while AFS President **L. H. Durdin** looks on with approval. Durdin was the banquet speaker.

Air-Set Cores: Application of the air-setting process fits ideally into jobbing shops making medium and large castings. On miscellaneous castings, more tonnage can be produced per given amount of floor space, and with a smaller, less skilled work force than by other methods, stated Daniel R. Chester, Archer-Daniels-Midland Co., Cleveland.

Next to cores, the biggest use for the process is as a dry mold facing backed up with regular molding sand. Close tolerances and frequent elimination of baking have been the major advantages.

Noise: Noise is unique in the compensation field since loss of hearing affects one-half of the population, remarked Floyd E. Frazier, National Association of Mutual Casualty Companies, Chicago.

Until recent years, disability schedules applied only when the worker suffered a loss of wages. New York and Wisconsin court rulings now hold that loss of hearing is an occupational disease and compensable, even without the loss of wages.

Frazier pointed out that factory and foundry noise is only one factor contributing to deafness; others are childhood diseases, use of certain drugs and ordinary noise. The problem is further complicated since it cannot be determined how much noise contributed to the loss of hearing and how much has been caused by other factors.

A. F. Gross

C. M. Adams

H. W. Lownie

. . at Southeastern Regional Meeting

Frazier had the following recommendations for foundry management:

1. Make a noise survey in the foundry.
2. Test the hearing of new workers with an audiometer.
3. Provide workers with personal protective equipment.
4. Install engineering controls such as mufflers and isolation of personnel and machinery.

Automation: Design and operation of an automatic pouring and molding operation in a Swiss malleable iron foundry were described by Alex Homberger, International Automation Corp., Ann Arbor, Mich. Operation of the system was also shown in a movie.

The installation produces 300 molds per hour with pattern changes completed within approximately one minute. Clay bonded sand is used as the molding medium with the mold first pre-compacted by jolting and compacted in the final stage by jolt-squeezing.

A new type, highly subdivided pattern plate was designed to accomodate a mold gripping and stripping device which prevents the mold flask from tilting during stripping operations. The clamping frame allows for a quick exchange of the individual pattern plates and also for the use of a much greater variety of pattern plates.

Metal is automatically poured from a bottom-stopper ladle into a pouring ladle. Emptying the pouring ladle independently of the filling of mold cavities, placing the pouring basin in the same position on each mold, use of an improved tilting mechanism, all these have made it possible to automate the pouring operation in the Burher method.

Management: The day of the central directing personality in company affairs is rapidly disappearing from the American scene as corporations continue to grow in size, observed Dr. Fred A. Replogle, Rohrer, Hibler and Replogle, Chicago. Today's progressive companies are likely to be directed by a professional manager or management team.

Companies, regardless of size, must build an organization to continue as a strong and vital force. They must adopt a philosophy of what their basic purpose is and how they hope to accomplish it.

"The organization is only a vehicle to carry out the plan or philosophy. With a statement of policy most problems are 75 per cent solved," said Replogle.

Top management today must know how to think, plan and manage.

Risering: Problems of mold wall movement and riser sizes needed to offset the effects of mold wall movement and casting shrinkage were discussed by Clyde M. Adams, Massachusetts Institute of Technology, Cambridge, Mass.

Through slides and charts he demonstrated the thermal loss of several metals under various mold and risering conditions. Heat loss through risers was explained in terms of per cent lost by radiation. Because of its high melting temperature and emissivity, it was pointed out that steel ranked comparatively high in this type of heat transfer.

It was noted that in the risering of gray iron castings that the natural reduction in volume during solidification may be essentially complete when the metal is only 20 per cent solid. Subsequent solidification may actually result in a volume increase.

Adams showed that in gray iron, green sand castings dilate, demand more feed metal and require larger risers to guarantee soundness than do dry sand molds. In practice, a green sand casting should either have no riser at all, or a riser adequate to feed a casting poured in a mold having mold wall movement tendencies.

Quality Control: Detailed statistical quality control is best suited for long-run production. However, steps can be taken on small-run production to tighten foundry practice through control of variables.

How this can be accomplished was explained by Arthur F. Gross, Ohio Steel Foundry Co., Lima, Ohio.

Standardization of melting practice, pouring temperatures and techniques and inspection methods frequently can be enforced to eliminate many of the variables.

Well-designed forms for the reporting and circulation of pertinent design, inspection and production data was also recommended. Such charts are the flow chart of manufacture, job sheet, inspection flow chart and trouble analysis sheet. These aid in providing controls necessary for present and future reproducibility.

Future: Continued technological advances in the foundry industry were predicted by AFS General Manager Wm. W. Maloney. He cited the processes and techniques developed within the past 15 years and envisioned advances as great or greater in the next 15 years.

Maloney described the accomplishments of the AFS Training & Research Institute program started in 1956. He also commented on the proposed T&RI Training Center on which bids will be received in fall. If approved by the AFS Executive Committee, the building will be constructed adjoining the present AFS Headquarters which is located in Des Plaines, Ill.

Ladies attending the **Southeastern Regional** Foundry Conference enjoyed a full two-day program. Shown at the ladies reception are past Birmingham Chairman **Sam Carter** and wife. In background at right is AFS National Director **C. A. Sanders** and wife.

T&RI Shifts to West Coast

■ T&RI activities will resume in April following the Annual Convention with the presentation of *Gating & Risering of Castings* coursese in California. Next will be *Melting of Copper-Base Alloys* to be given in Hamilton, Ontario. All three will be co-sponsored with AFS Chapters.

Dates and locations:

April 24-25—Gating & Risering of Castings, Rodger Young Auditorium, Los Angeles.

April 27-28—Gating & Risering of Castings, Claremont Hotel, Berkeley, Calif.

May 4-5—Melting of Copper-Base Alloys, Royal Connaught Hotel, Hamilton, Ontario.

Instructors for the West Coast courses will be John Varga, Jr., Battelle Memorial Institute, Columbus, Ohio; AFS Technical Director S. C. Massari and AFS Training Supervisor R. E. Batterley.

Outline of subjects in Gating & Risering of Castings:

Basic Fundamentals—Heat transfer, fluid flow of metals.

Horizontal Gating—Research report AFS film "Effect of Horizontal Gating Design on Casting Quality."

Gating of Ferrous Castings—Functions of ideal gating system, establishing the system, optimum pouring time, designing a gating system, examples, conclusions.

Risering of Ferrous Castings—Solidification of gray iron, microporosity, mold materials and risering, casting design and mass, selection of riser size and location, selection of riser necks and dimensions, maintaining recommendations.

Vertical Gating—AFS research film "A Study of Vertical Gating Design."

Gating & Risering of Non-Ferrous Alloys—Nature of materials under consideration, pouring practice, gating practice, risering non-ferrous alloys, venting practice, pouring temperature practice, chills, insulators, exotherms.

"Metal Flow in Molds,"—film, Institute of British Foundrymen.

Melting of Copper-Base Alloys

Tentative schedule of subjects for course at Hamilton, Ont.

Classification of Alloys—Scope, basis of classification.

Melting Equipment—Basic concepts, electric furnaces, fuel-fired furnaces.

Control of Melt Quality—Furnace, raw material, effect of refractories, foreign materials, furnace atmosphere, fluxes, temperature control.

Test Procedures for Quality Control—Importance, fracture tests, specific gravity, fluidity, deep-etch test, pressure testing.

Other courses in May include *Cupola Melting of Iron* to be given May 11-15 in Chicago and *Metallurgy of Gray Iron* to be given May 25-27 in Chicago.

No courses are scheduled for June but the program resumes in July with *Metallography of Non-Ferrous Metals* in Chicago followed by two August courses in Chicago. These are *Core Sand Practice*, Aug. 10-14; and *Gating & Risering of Castings*, Aug. 24-26. Chicago courses are held in downtown hotels.

1959 T&RI Courses

April-July

Subject and Description — *Dates*

Gating & Risering of Castings .... April 24-25
Instruction course covering theory and practice on the various problems relating to gating and risering. Metal flow, solidification phenomena, heat transfer, shrinkage, hot tears, ferro-static pressure, gate and riser design, mold wall movement, and surface tension are some of the many facets covered. Intended for foremen, technicians, foundry engineers, supervisors, industrial engineers and production and quality control personnel. Course to be presented in Los Angeles; fee, $45.

Gating & Risering of Castings .... April 27-28.
Above course to be presented at Berkeley, Calif. Fee, $45.

Melting of Copper-Base Alloys .... May 4-5
Course of instruction for melters supervisors, metallurgists and foremen. Nomenclature, alloy classification, melting fundamentals, equipment, controls, testing and raw materials. Basic control variables are considered in light of optimum results. Course M2A, $45, Hamilton, Ont.

Cupola Melting of Iron .... May 11-15
Instructional course for cupola operators, supervisors, metallurgists and foremen. Basic principles for efficient cupola operation are studied with emphasis on cost reduction. Raw materials, cupola design, combustion control, metallurgy of cast iron, maintenance and new developments. Course M3A, $90, Chicago.

Metallurgy of Gray Iron .... May 25-27
Intensive instruction on the basic metallurgy of gray iron. Metal compositions, alloys, physical and mechanical properties. Photo-micrographic examples are shown with the interpretation of microstructures. Controlling mechanical properties. For melters, metallurgists, engineers, researchers, supervisors and management. Course MET1A, $60, Chicago.

Metallography of Non-Ferrous Metals ..... July 13-15
Demonstration and work shop course for melters, supervisors, foremen, foundry engineers, researchers, laboratory technicians, metallurgists and design engineers. Basic metallurgy, terminology, phase diagrams, micro and macro analysis, mechanical properties based on metallographic interpretation and heat treatment are studied. One day on demonstrations and workshop activities in the laboratory. Metal specimens are prepared and studied. Course MTY2A, $80, Chicago.

chapter news

First place winner in metal patternmaking was James Arnold, Progress Pattern Co. —*E. A. Swensson*

St. Louis Chapter members at the January meeting heard R. A. Witschey, A. P. Green Fire Brick Co., Mexico, Mo., speak on **Fundamental of Refractories.** Left to right are speaker Witschey and Technical Chairman S. Fredericks, American Steel Foundries, Granite City, Ill. Chapter Chairman W. C. Pickles, National Bearing Div., American Brake Shoe Co., St. Louis, presided at the meeting held at Edmond's restaurant. A refreshment period preceeded the meeting. —*H. V. Boemer*

K. A. Miericke, Baroid Div., National Lead Co., Chicago, was the non-ferrous speaker at the **Chicago Chapter** February meeting. His subject, **Oil-Bonded Molding Sands.** —*N. A. Baranov*

M. H. Horton, Deere & Co., Moline, Ill., spoke on **Operation of Acid and Basic Water-Cooled Cupolas** at the **Chicago** February meeting. **H. G. Haines,** Woodruff & Edwards, Elgin, Ill., chairman of the chapter's gray iron division is on the right.

St. Louis Chapter

Veining and Penetration

■ Approximately 115 members at the February meeting heard George DiSylvestro, American Colloid Co., Skokie, Ill., speak on *Veining and Penetration.*

Thirteen apprentices were presented with awards at the annual Apprentice Training Award Night.

—*R. E. Hard*

Central New York Chapter

Celebrates 20th Anniversary

■ Members observed the 20th anniversary of the chapter at its February meeting. H. J. Weber, AFS Director of Safety, Hygiene & Air Pollution Control Program spoke on *The Impact of Air Pollution Laws on Foundries.*

Weber criticized state legislatures which adopt air pollution laws passed by other states. He stated that many state bodies have little or no knowledge of what they are adopting. In many cases the laws were developed for fuel burning equipment such as power stacks which are not realistic for foundries. In many cases foundries can not comply with the laws. In many cases foundries will have to spend $20,000 to $120,000 to comply with specifications and still have no assurance of being within the law.

—*C. W. Diehl*

Connecticut Chapter

Facilities for Jobbing Shops

■ The importance of the use of versatile equipment to suit the jobbing foundry mechanization of molding, coremaking, sand preparation, casting, cleaning, melting and material handling were stressed at the February meeting by Glenn W. Merrefield, Giffels & Rossetti, Detroit.

G. W. Merrefield

Slides were shown of two foundry projects in jobbing foundries where good engineering on modern facilities improved casting quality and reduced costs.

Detroit Chapter

Local Apprentice Winners

■ Judging in the Detroit chapter apprentice contests was held Jan. 31. Winners in the wood patternmaking division were: 1st, D. A. Giles, Beaver Pattern Co.; 2d, A. J. Kravetz, Progress Pattern Co.; 3d, Joseph Gross, Automotive Pattern Co.

V. B. **Roll,** Kish Industries, Milwaukee, spoke on **Plastics for the Pattern Industry** at the **Chicago** February meeting. On left is **John MacDonald,** Pettibone Mulliken Corp., Chicago, chairman of the chapter's pattern division.

Lawrence Winnings, Wagner Castings Co., Decatur, Ill., (left) spoke on casting porosity at the **Chicago** February meeting. G. Sliwinski, National Malleable & Steel Castings Co., Cicero, Ill., chairman of the chapter's malleable division, is on right.

chapter news

Tri State Chapter

High-Pressure Molding

■ Green strengths in molding sands in excess of 10 psi result in ultimate green sand casting strength, T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill., stated at the February meeting. These high strengths, he said, are obtained by the use of bentonites in excess of 10 per cent. Organic and cellulose materials are then added. Although this type sand is harder to compress, it results in more stable molds resulting in more accurate ferrous and non-ferrous castings.

William Chadwick, Manley Sand Co., Rockton, Ill., showed a film dealing with sand segregation.

—Leslie O'Brien

Michiana Chapter

Automated Pouring, Molding

■ Automation accomplished by the Buhrer method was explained at the February meeting by Alex Homberger, International Automation Corp., Ann Arbor, Mich.

Complete automation exists from the initial sand in the drag part of the mold to the shakeout and return of flask to the molding station. Mechanical-pneumatic principles are used to provide automated flexibility, using nine men where 60 were required previously.

A maximum of 300 molds can be processed hourly. Production can be varied in small increments from the maximum of 300 hourly down to about 150 molds per hour minimum.

—Walt Ostrowski

Western New York Chapter

Automation in the Foundry

■ Production of 300 molds hourly with nine men using an automatic pouring and molding installation was explained at the February meeting by William Illuminati, International Automation Corp., Ann Arbor, Mich.

Automation includes molding of drag and cope molds; closing of molds; weighing-down of molds; pouring; mold cooling; shakeout; bottom plate, cope and drag flask separation and return; sand feed and return.

Program cycling devices operate on the mechanical-pneumatic principle.

—Don Kreuder

Daniel Chester, Archer-Daniels-Midland Co., Cleveland, spoke on **Quality Control in the Coreroom** at the February meeting of the **New England Chapter**. Chester pointed out that many of the difficulties with the CO_2 and air-setting binders can be traced to deviation from recommended practices. Shown in photo: speaker **Chester** and New England Chapter President **William N. Ohlson**, Draper Corp., Hopedale, Mass.

—J. H. Orrok and F. S. Holway.

Attending **Northern California** February meeting were **Charles Schuerman**, consultant, and **Malcom McGregor**, General Metals Corp., Oakland, Calif.

Foundrymen talking with guest speaker at February meeting of **Western Michigan** Chapter. Left to right: **Clifford Lonnee**, Alloyed Grairon Castings Corp., Ravenna, Mich.; speaker **George O. Pfaff**, Wheelabrator Corp., Mishawaka, Ind.; Chapter Vice-Chairman **E. J. Carmody**, Engineering Foundry Inc., Cedar Springs; **James C. Kurz**, MODERN CASTINGS.

—Dan Connell

Four visitors from other chapters attended the January meeting of the **Northwestern Pennsylvania** Chapter. Left to right: **Herb Cutler**, American Fire Clay & Products Co., and **J. H. Sibbison, Jr.**, Kerchner, Marshall & Co., both from the Northeastern Ohio Chapter; **R. E. Turner**, Queen City Sand & Supply Co., and **G. F. Goetsch**, Sterling National Industries, Inc., both from Western New York Chapter.

—Walter Napp

Cincinnati Chapter

Foundry Quality Control

■ Development and installation of foundry quality control programs at the Indianapolis International Harvester Co. plant were explained at the February meeting by Allen A. Evans. Examples of savings were cited as proof of the effectiveness of the systems.

—J. D. Claffey

Student and faculty of AFS **Michigan State University Student Chapter.** Left to right, front row: Vice-Chairman **Donald Wolfrum**; Chairman **George Shufelt**; Advisor Dr. **D. D. McGrady**; Advisor Prof. **C. C. Sigerfoos**; Corresponding Secretary **Frederick Slovinski**; Secretary-Treasurer **John C. Bierlein.** Second row, left to right: **John Domster; John Harbison; Tom Holz; Harry L. Murphy; Paul Das.** Third row, left to right: **Robert Williams; Richard Carpenter; Walter Rensel,** Jr.; **Milan Savich; Richard Williams, Ronny Merlington.**

Continuous injection of carbon into gray cast irons on a production basis was explained to **Eastern Canada Chapter** members at the February meeting by J. E. Rehder, Canada Iron Foundries, Ltd. Left to right: **Henry Louette,** Warden King Ltd.; **George Turnbull,** Canada Iron Foundries Ltd.; **Ewing Tait,** Dominion Engineering Works, Ltd.; Ontario Chapter Chairman **John Hughes,** Steveson-Kellogg Ltd.; Eastern Canada Chapter Chairman **Max Reading,** Foundry Services (Canada) Ltd.; **J. E. Rehder,** Canada Iron Foundries, Ltd.; **Marcell Trottier,** Quebec Iron & Titanium Ltd.; **Raoul Desillets,** Sorel Steel Foundries, Ltd.; **Alf Lewis,** Crestweld Mfg. Ltd.; Chapter Secretary **Leo Myrand,** Montreal Foundry Ltd. *—Robert B. Hill*

Foundry mechanization on a small scale was explained at the January meeting of the **Eastern Canada Chapter** by H. W. Zimnawoda, National Engineering Co. of Canada. Reading left to right at speakers table are: **R. B. Hill,** Dominion Bridge Co. Ltd.; **John Hunt,** Canadian Bronze Ltd.; **Marcell Trottier,** Quebec Iron & Titanium Ltd.; **Jack Moore,** Canadian Bronze Ltd.; Chapter Chairman **Max Reading,** Foundry Services (Canada) Ltd.; speaker **H. W. Zimnawoda; G. K. Scanlon,** Canadian Foundry Supplies & Equipment Ltd.; **Alf Lewis,** Crestweld Mfg. Co.; **Lucien Guilmette,** Canadian Foundry Supplies Ltd.; **Leo Myrand,** Montreal Foundry Ltd.

Shown at February meeting of **Michiana Chapter** are: **Tom Reuwer,** Sibley Machine & Foundry Corp., South Bend, Ind.; **Vince Bruce,** Frederic B. Stevens, Inc., Indianapolis; **Stanley Kreszewski,** Wheelabrator Corp., Mishawaka, Ind.; **Alex Homberger,** International Automation Corp., Ann Arbor, Mich.; **Robert Hull,** Casting Service Corp., La Porte, Ind.; **Howard Vorhees,** Mishawaka, Ind.; **Bill Patterson,** Elkhart Foundry & Machine Corp., Elkhart, Ind.; **Emery Soose,** Studebaker-Packard Corp., South Bend, Ind.

New **Central New York** members are flanked on left by past Chapter Chairman **John Feola,** Crouse Hinds Co.; and on right by National Director **William D. Dunn,** Oberdorfer Foundries. Left to right are: **Rudolph Ivanchak,** Fay Foundry; **John Cheny,** Crouse Hinds Co.; **Kenneth Shay** and **Robert Abend,** Oberdorfer Foundries; **Mortimer Meltzer** and **William Nicholson,** Roth Smelting Co. *—C. W. Diehl*

Ontario Chapter

Modern Foundry Refractories

■ Research and development programs in the refractories field were discussed at the January meeting by L. Gill, Harbison-Walker Refractories Co., Pittsburgh, Pa. Manufacturing problems were also outlined.

Twenty-one students from McMaster University and the University of Toronto attended as guests of the Chapter. A tour was made of the American Standard Products (Canada) foundries. *—M. Dillon*

A film on the Buehrer system of automation was presented at the January meeting of the **Western New York** Chapter by **William Illuminati,** International Automation Corp., Ann Arbor, Mich. On the left is Illuminati standing with Technical Chairman **S. J. Santomieri,** Worthington Corp., Buffalo, N. Y. *—Walter Napp*

R. A. Clark, Electro Metallurgical Co., Div. Union Carbide Corp., Cleveland, (on right) receives wallet from **Pittsburgh Chapter** Chairman **I. W. Sharp,** American Steel Foundries, Verona, Pa. Clark spoke at the January meeting on "Metallurgy of Cast Iron." *—Walter Napp*

San Antonio Section

Foundry Sands and Binders

■ Art Zrimsek, Magnet Cove Barium Co., Des Plaines, Ill., at the January meeting, discussed foundry sands and binders. He described tests made on binders, sands and materials. The meeting was held at K. O. Steel Castings, Inc., San Antonio, Texas.

Ray Silva, Fairbanks-Morse Co., Pomona, Calif., addressed the **Northern California** Chapter in February on **Air Set Process.** Shown at head table are: Chapter Vice-President **Donald C. Caudron,** Pacific Brass Foundry of San Francisco, San Francisco; speaker **Ray Silva;** Chapter President **Gordon L. Martin,** Atlas Foundry & Mfg. Co., Richmond, Calif.; Chapter Director **B. F. McDonald,** Pacific Graphite Co., Oakland, Calif.

T. E. Eagan, Cooper-Bessemer Corp., Mt. Vernon, Ohio, spoke at the **Northwestern Pennsylvania Chapter** in January on various grades of iron. Left to right are Technical Chairman **J. D. James,** Urick Foundry Co., Erie, Pa. and speaker Eagan. Due to the heavy snow, the scheduled speaker was unable to be present.
—*Walter Napp*

Speakers table at February **Tri State** February meeting. Membership Chairman **Frank M. Scaggs,** Oklahoma Steel Castings Co., Div. American Steel & Pump Corp., Tulsa, Okla.; Chapter Chairman **Emmett F. Hines,** Nemco Foundry Co., Div. Nelson Electric Mfg. Co., Tulsa, Oklahoma; speaker **Tom Barlow,** Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill.; speaker **William Chadwick,** Manley Sand Co., Rockton, Ill.; Chapter Vice-Chairman **William Pitts,** Oklahoma Steel Castings Co., Div. American Steel & Pump Corp., Tulsa, Okla.

Central Michigan Chapter

Cutting Blast-Cleaning Costs

■ Ways of reducing blast cleaning costs were explained to members at the February meeting by G. O. Pfaff, Wheelabrator Corp., Mishawaka, Ind.

Pfaff spoke on controlling blast cleaning efficiency, controlling abrasive losses and standard operating and maintenance practices and cost controls. In addition, a film "Steel Shot" was shown. Pfaff stated that accurate and comparative cost controls provide management the best assurance of continued low cost and uniform high quality production.
—*F. H. Hutchins*

Western Michigan Chapter

Reducing Blast Cleaning Costs

■ Abrasive costs constitute one of the major cleaning room expenses, any appreciable reduction in abrasive consumption will automatically lower cleaning room costs and increase profits, G. O. Pfaff, Wheelabrator Corp., Mishawaka, Ind., told foundrymen at the February meeting.

He recommended accurate and comparative cost controls as a means of obtaining low cost and uniform high quality production. To operate efficiently and economically, blast cleaning equipment must throw the proper amount of the proper abrasive mixture in the proper place, he said.
—*Dan Connell*

afs | chapter meetings

APRIL						
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APRIL

Birmingham District . . April 10 . . Thomas Jefferson Hotel, Birmingham, Ala. . . M. H. Horton, Deere & Co., *"Basic Cupola Operation."*

British Columbia . . April 17 . . Leon's, Vancouver, B.C. . . K. A. Skeie, Magnaflux Corp., *"Castings Inspection for Profit."*

Canton District . . April 2 . . Elks Club, Barberton, Ohio . . F. J. Pfarr, Lake City Malleable Co., *National Officers' Night and Film, "American Engineer."*

Central Illinois . . April 6 . . American Legion Hall, Peoria, Ill. . . G. W. Anselman, Whirl Air Flow Co., *"Pneumatic Handling Improves Sand Quality."*

Central Indiana . . April 6 . . Athenaeum, Indianapolis . . F. K. Baldauf, Wheelabrator Corp., *"What's New in Airless Blast Cleaning."*

Central Michigan . . April 22 . . Hart Hotel, Battle Creek, Mich.

Central New York . . April 24 . . Statler Hall, Cornell University, Ithaca, N.Y. . . A. H. Homberger, International Automation Corp., Film, *"Buhrer Automated Molding & Pouring Methods."*

Chesapeake . . April 24 . . Engineers' Club, Baltimore, Md. . . *Round Table and Casting Clinic.*

Chicago . . April 6 . . Chicago Bar Association, Chicago . . *Non-Ferrous Group*: J. N. Atols, Atols Tool & Mold Corp., *"Shaw Process for Casting Dies & Permanent Molds"; Gray Iron & Pattern Group*: J. F. Wallace, Case Institute of Technology, *"Gating & Risering of Gray Iron"; Steel Group*: F. W. Boulger, Battelle Memorial Institute, *"Effects of H_2 &N_2 on Ductility & Porosity of Steel Castings"; Malleable Group*: A. W. Johnson, Northern Malleable Co., *"Shell Cores & their Practical Uses"; Maintenance Group*: F. Bergquist, National Malleable & Steel Castings Co., *"General Foundry Maintenance Problems."*

Cincinnati District . . *No Meeting.**

Connecticut . . April 28 . . Waverly Inn, Cheshire, Conn. . . G. W. Anselman, Whirl Air Flow Co., *"Casting Defects."*

Detroit . . *No Meeting.**

Eastern Canada . . April 10 . . Sheraton Mt. Royal Hotel, Montreal, Que. . . *Steel*: T. Niven, Canadian Steel Foundries, Ltd.; *Iron*: F. Sutherland, Dominion Engineering Works, Ltd.; *Bronze*: R. Woods, Canadian Bronze Co. Ltd., *Panel Discussion on Chilling.*

Eastern New York . . April 21 . . Panetta's Restaurant, Menands, N.Y.

Metropolitan . . Essex House, Newark, N.J. . . *Purchasing*: J. W. Foster, Ingersoll-Rand Co.; *Engineering*: A. R. Mead, Grumann Aircraft Eng. Corp.; *Navy*: W. H. Baer, U.S. Bureau of Ships; *"What Is Expected of Casting from Viewpoint of Purchasing, Engineering and Navy."*

Mexico . . April 20 . . Ave. Chapultepec 414, Mexico D.F. . . V. Nacher Todo, La Consolidada S.A., *"Use of Oxygen in Open Hearth Furnaces."*

Michiana . . *No Meeting.**

Mid-South . . April 10 . . Hotel Claridge, Memphis, Tenn. . . W. E. Jones, Josam Mfg. Co., *"Hidden Foundry Costs."*

Mo-Kan . . April 3 . . Fairfax Airport Kansas City, Kan.

New England . . April 8 . . Sloan Bldg., Massachusetts Institute of Technology, Cambridge, Mass.

Northeastern Ohio . . April 9 . . Tudor Arms Hotel, Cleveland . . M. K. Young, U. S. Gypsum Co., *"Plaster & Plastics Material for Foundry Industry."*

Northern California . . April 13 . . Spenger's, Berkeley, Calif. . . K. A. Skeie, Magnaflux Corp., *"Castings Inspection for Profit."*

Northern Illinois & Southern Wisconsin . . April 14 . . Lafayette Hotel, Rockford, Ill. . . C. Schwyhart, Caterpillar Tractor Co., *"Foreman Training."*

Northwestern Pennsylvania . . April 27 . . Amity Inn, Erie, Pa. . . R. W. Zillman, Pittsburgh Steel Foundry Corp., *"Shooting CO_2 Cores."*

Ontario . . *No Meeting.**

Oregon . . April 15 . . Heathman Hotel, Portland, Ore. . . K. A. Skeie, Magnaflux Corp., *"Castings Inspection for Profit."*

Philadelphia . . April 10 . . Engineers' Club, Philadelphia . . S. F. Carter, American Cast Iron Pipe Co., *"Electric Arc Furnace Operation."*

Piedmont . . *No Meeting.**

Pittsburgh . . April 20 . . Hotel Webster Hall, Pittsburgh, Pa. . . C. A. Sanders, American Colloid Co., *"Casting Finish Precision & Tolerance."*

Quad City . . April 20 . . LeClaire Hotel, Moline, Ill. . . A. Homberger, International Automation Corp., *"Buhrer Automated Process."*

Rochester . . April 7 . . Manger Hotel, Rochester, N.Y. . . C. A. Sanders, American Colloid Co., *"Casting Defects–A Foundry Disease."*

Saginaw Valley . . April 2 . . Fischer's Hotel, Frankenmuth, Mich. . . E. E. Braun, Central Foundry Div. GMC, *"New Approach to Marketing Castings."*

St. Louis District . . April 9 . . Edmond's, St. Louis . . J. Chahbandour, Carrier Conveyor Corp., *"Application of Vibrating Equipment in Modern Foundry Practice."*

Southern California . . April 10 . . Rodger Young Auditorium, Los Angeles . . K. A. Skeie, Magnaflux Corp., *"Castings Inspection for Profit."*

Tennessee . . April 24 . . Patten Hotel, Chattanooga, Tenn. . . J. Webb, Union Carbide Corp., *"Effect of Research on the Future."*

Texas . . April 24 . . Angelina Hotel, Lufkin, Texas . . *Castings Clinic.*

Toledo . . April 1 . . Heatherdowns Country Club, Toledo, Ohio . . J. A. Babcock, Pickands Mathers & Co., *"Mining & Smelting of Taconite Ore."*

Tri-State . . April 10 . . Holiday Inn Motel, Oklahoma City, Okla. . . *Round Table Discussion.*

Twin City . . April 7 . . Jax Restaurant, Minneapolis . . T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., *"Significance of Various Sand Tests."*

Utah . . April 20 . . Covey Hot Shoppes, Salt Lake City . . K. A. Skeie, Magnaflux Corp., *"Castings Inspection for Profit."*

Washington . . April 16 . . Engineers' Club, Seattle . . K. A. Skeie, Magnaflux Corp., *"Castings Inspection for Profit."*

Western Michigan . . April 6 . . Schnitzelbank, Grand Rapids, Mich. . . Prof. Jenkins, Michigan State University, *"Creative Thinking."*

Western New York . . April 4 . . Trap & Field Club, Buffalo, N.Y. . . *Annual Spring Dinner Dance.*

Wisconsin . . April 6 . . Schroeder Hotel, Milwaukee . . A. H. Mogensen, *"Work Simplification."*

* Many Chapters have canceled April meetings to avoid conflict with AFS Engineered Castings Show.

MAY

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MAY

Corn Belt . . May 1 . . Steeple House, Beatrice, Neb.

Mo-Kan . . May 1 . . Fairfax Airport, Kansas City, Kans.

Piedmont . . May 1 . . Hotel O'Henry, Greensboro, N.C. . . R. Carlson, American Cast Iron Pipe Co., *"Cupola Operations."*

Central Illinois . . May 4 . . Vonachen's Junction, Peoria, Ill. . . C. E. Fausel, Central Foundry Div., GMC, *"Air Pollution Laws Affecting Foundries,"* and H. J. Weber, AFS, *"The Noise Problem in Foundries."*

Central Indiana . . May 4 . . Athenaeum, Indianapolis . . *Panel*: J. A. Crumley, Deere & Co.; G. R. Slick, Beckett Bronze Co.; W. M. Grimes, Gartland Foundry Co.; H. W. Carmichael, Nonferrous Foundries, Inc.; O. L. Wilhelm, Delco Remy Div., GMC. *Moderator*: R. Fickenworth, Bruce-Conreaux Co., *"Know Your Local Area Foundries" and Past Chairmen's Night.*

Chicago . . May 4 . . Chicago Bar Association, Chicago . . A. Homberger, International Automation Corp. *Film, "Buhrer Automated Molding & Pouring Methods."*

Metropolitan . . May 4 . . Essex House, Newark, N.J. . . J. Mikulak, Worthington Corp. and L. Palmer, American Metaseal Corp., *"Welding & Impregnation of Pressure Castings."*

Western Michigan . . May 4 . . Bill Stern's Restaurant, Muskegon, Mich. . . E. Hines, *"Foundry Costs."*

Rochester . . May 5 . . Manger Hotel, Rochester, N.Y. . . *Election of Officers.*

Saginaw Valley . . May 7 . . Fischer's Hotel, Frankenmuth, Mich. . . C. C. Sigerfoos, Michigan State University, *"Central American Foundries."*

Western New York . . May 7 . . Sheraton Hotel, Buffalo, N.Y. . . *Annual Smorgasbord Dinner.*

Birmingham District . . May 8 . . Birmingham, Ala. . . J. Delisa, General Electric Co., *"Nondestructive Testing of Castings."*

Central New York . . May 8 . . Drumlin's Country Club, Syracuse, N.Y.

Mid-South . . May 8 . . Claridge Hotel, Memphis, Tenn. . . *Election of Officers.*

Philadelphia . . May 8 . . Engineers' Club, Philadelphia . . M. A. Cavanaugh, Budd Co., *"Peventive Maintenace."*

Southern California . . May 8 . . Rodger Young Auditorium, Los Angeles . . K. F. Sheckler, Calmo Engineering Co., *"Refractories–Uses in the Foundry."*

Tri-State . . May 8 . . Alvin Plaza Hotel, Tulsa, Okla. . . W. R. Jaeschke, Whiting Corp., *"Cupola Practice."*

Wisconsin . . May 8 . . Schroeder Hotel, Milwaukee . . *Old Timers' and Apprentices' Night.*

Central Ohio . . May 11 . . Seneca Hotel, Columbus, Ohio.

Cincinnati District . . May 11 . . Hotel Alms, Cincinnati . . B. D. Claffey, G.H.R. Foundry, Div. Dayton Malleable Iron Co., *"Shell Molding & Shell Coremaking."*

Northern California . . May 11 . . Spenger's, Berkeley, Calif. . . *Heat Treat Panel.*

Twin City . . May 12 . . Jax Restaurant, Minneapolis . . O. J. Myers, Reichhold Chemicals, Inc., *"Resin Core Binders."*

Northeastern Ohio . . May 14 . . Tudor Arms Hotel, Cleveland . . *Recognition Night–Apprentices, Old Timers, National Officers, Past Chairmen.*

St. Louis District . . May 14 . . Edmond's Restaurant, St. Louis . . C. V. Nass, Beardsley & Piper Div., Pettibone Mulliken Corp., *"Mechanization of Molding."*

Pittsburgh . . May 17 . . Webster Hall Hotel, Pittsburgh, Pa. . . J. W. Early, J. S. McCormick Co., Educational Meeting, Also Honoring 50-year Men.

Central Michigan . . May 20 . . Hart Hotel, Battle Creek, Mich.

Oregon . . May 20 . . Heathman Hotel, Portland, Ore. . . *Business Meeting. Program in Conjunction with Oregon State College Student Chapter.*

Detroit . . May 21 . . Wolverine Hotel, Detroit . . E. J. Mapes, Pickands Mather & Co., *"Horizons North."*

CO_2 Process Breaks The Size Barrier

JAMES W. HAMBLEN
*Cardox Division
Chemetron Corp.,
Chicago*

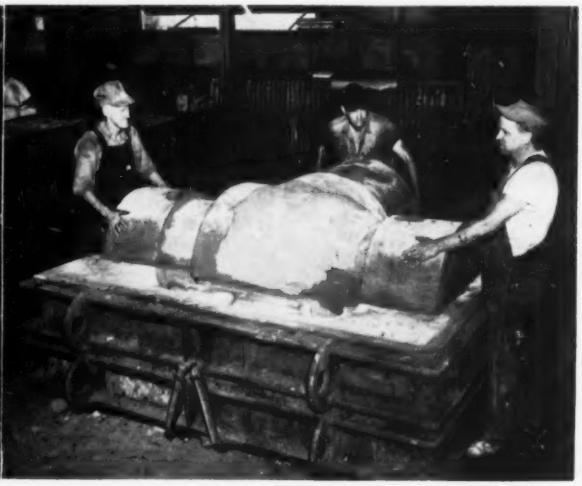
Inside view of 30-in. valve casting with heads and gate removed. Fewer cracks and cleaner surfaces were observed on all sizes of castings produced with the CO_2 process.

The 30-in. valve shown here is the largest single piece to be cast at Oklahoma Steel Castings Co., Tulsa, Okla., using cores produced by the CO_2 foundry process. When the 4410-lb valve was first cast in 1957, we knew of no valve casting of similar size having been attempted with the CO_2 process.

Prior to proving the feasibility of casting such large valves with CO_2 cores, Oklahoma Steel limited their use to a maximum size of 6-in. valves weighing 50 lb.

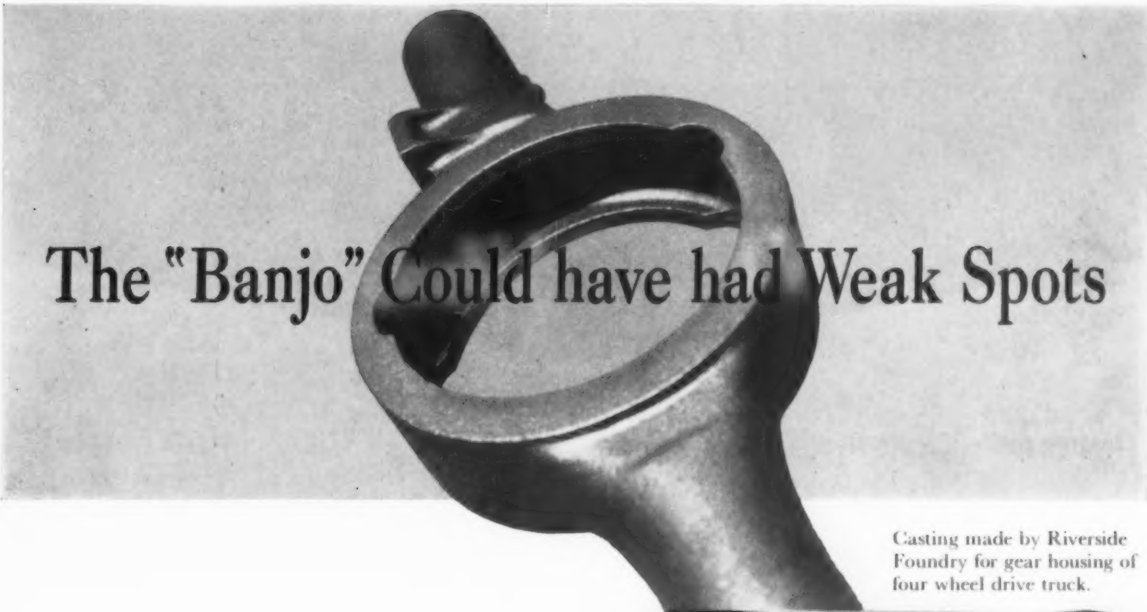
The CO_2 process was introduced at Oklahoma Steel Castings in June 1955 and has since grown to be the major coremaking method used in this foundry. The chief advantages of this system are: 1) finer finishes, 2) much higher degree of dimensional accuracy, 3) definite reduction in production costs, and 4) greater flexibility in production schedules because of elimination of long baking cycles.

Drag core weighing 2700 lb is being set into the mold. Core was produced on wooden shell patterns and CO_2 gassed for about 25 minutes.

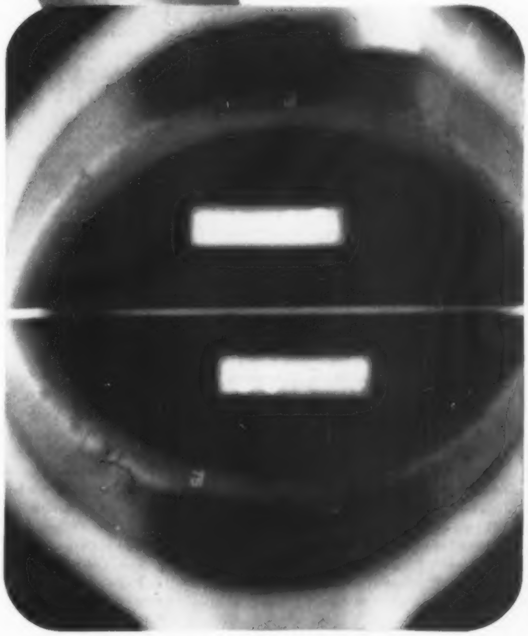


The cope half of the core has been set and pasted on the drag half, ready for the mold cope to be set and clamped in place for pouring.

The "Banjo" Could have had Weak Spots



Casting made by Riverside Foundry for gear housing of four wheel drive truck.



Radiograph reveals shrinkage and dirt

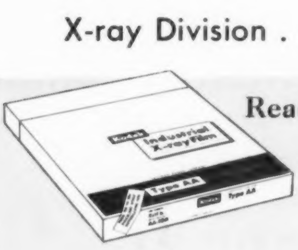
Casting this gear housing presented problems. Yet it had to be sound because it was destined for service in rugged, four-wheel drive trucks.

To be sure that it would be ready for its job, the Riverside Foundry, Bettendorf, Iowa, x-rayed the pilot castings. The radiographs showed shrinkage and dirt inclusions. Changes in casting technic followed. Radiography proved the difficulties were overcome.

This is another example of how radiography quickly points the way to sound production—provides assurance that only high-quality work is delivered.

This is the way to build business. You should take advantage of radiography. If you would like to know how it can work profitably for you, talk it over with an x-ray dealer or write for a Kodak technical representative to call.

X-ray Division . . . EASTMAN KODAK COMPANY . . . Rochester 4, N.Y.



Kodak Industrial X-ray Film Type AA

Read what Kodak Industrial X-ray Film, Type AA, can do for you:

- Speeds up radiographic examinations.
- Gives high radiographic contrast, increased detail and easy readability at all energy ranges.
- Provides excellent uniformity.
- Reduces the possibility of pressure desensitization under shop conditions.

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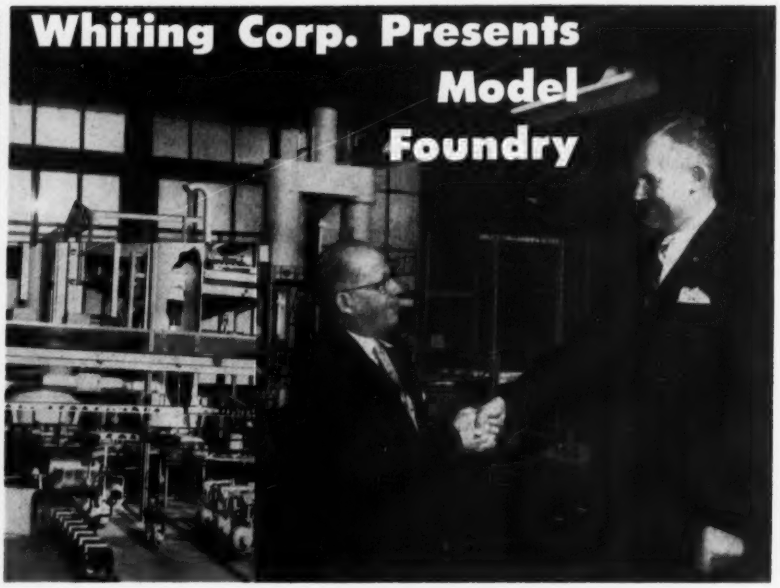
Circle No. 178, Page 167-168

Whiting Corp. Presents Model Foundry

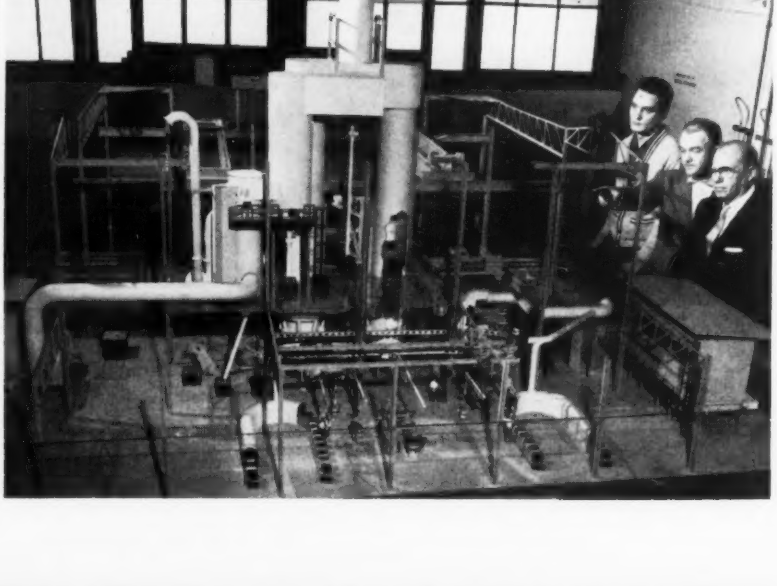


■ A complete scale model of a modern gray iron foundry was presented to the University of Illinois, Navy Pier Branch, Chicago, as a gift from the Whiting Corp., Harvey, Ill. Occupying a platform 8 ft x 8 ft, the miniature foundry has been appropriately erected in one of the laboratories where foundry practices are taught.

Picture shows Gordon E. Seavoy, vice-president, Whiting Corp., making the official presentation to Prof. Roy W. Schroeder (on left) who heads up the various courses on metalcasting technology at the university. The gift was a tribute to the extensive success of Prof. Schroeder in encouraging students to follow careers in the foundry industry.

Built at a cost of over $35,000, the miniature foundry (scale is ½ in. to the foot) has many operating components such as a scrap unloading magnet on an overhead crane, a charge bucket transfer car and a cupola charger. Raw materials are shown coming into the storage yard on railroad cars and being unloaded into bins.

Melting equipment consists of two 108-in. hot-blast cupolas with dust suppression facilities and a 10-ton electric-arc furnace. Students will become familiar with efficient plant layout, modern materials handling techniques and latest metalcasting methods with this unique teaching tool available.



foundry trade news

MALLEABLE FOUNDERS' SOCIETY . . . held its 4th Annual Technical & Operating Conference, Feb. 18-19, Cleveland. Over 100 malleable iron foundrymen absorbed two days of top technology arranged for by program Chairman Lyle R. Jenkins, Wagner Castings Co. After words of welcome from R. W. Crannell, Society president, the Conference discussed:

Metal: F. W. Jacobs, Texas Foundries, served as chairman of this session. The considerations in *"Selecting Pearlitic Malleable Manufacturing Equipment"* was elaborated on by **D. L. LaMarche, Jr.**, American Malleable Castings Co., **N. N. Amrhein**, Federal Malleable Co., and **L. E. Emery**, Marion Malleable Iron Works. LaMarche told about their economy-size installation suited for the plant just starting to break into the pearlitic field.

Amrhein described their thorough evaluation of equipment available on the market prior to making any purchase. Emery used slides to show all construction details of "Big Bertha"—their new 220 ft long, $800,000 heat treating furnace which represents about the ultimate in mechanization and automation. The metal session was concluded by **J. T. Bryce**, Albion Malleable Iron Co., speaking on *"Effect of Melting and Heat Treating on Temper Carbon."* Highlights of his talk revealed that . . . boron can be a graphitizer below 0.1 per cent and a carbide stabilizer above . . . first stage anneal determines graphite shape but not the number of nuclei . . . slow heating in first stage anneal increases carbon nodule count.

Foundry: This second session was chairmanned by A. Johnson, Northern Malleable Iron Co. First speaker was **C. A. Sanders**, American Colloid Co., on the subject *"Problems of Hot Molding Sand."* After discussing the causes of pinhole porosity, Sanders told the problems associated with hot sand and how to circumvent them. The second speaker, **L. H. Ravitch**, Central Foundry Div., GMC, told how to achieve *"Better Casting Design through Stress Analysis."* By using brittle lacquer and strain gage techniques, optimum casting designs are determined before parts go into production at GMC.

Third on this program was **L. C. Marshall**, Link-Belt Co., relating *"Progress in Machinability Research."* Dr. Marshall said, "Most important properties of materials probably are: microstructure, chemical composition and manufacturing process . . . for certain operations, oxide tools demonstrate a marked superiority."

Inspection & Testing: This third session was guided by Chairman P. F. Ulmer, Link-Belt Co. Lead-off man was **E. F. Price**, The Dayton Malleable Iron Co., telling about *"Inspection to Satisfy Customer Requirements."* While the speaker described cleaning room problems caused by poor foundry practices, sample castings were passed around the room for visual demonstration. Second speaker **R. C. McMaster**, Ohio State University, described all the modern techniques of *"Nondestructive Testing."* The latest improvements and theory operations were discussed.

Personnel: The concluding session had J. C. Goetz, Acme Steel & Malleable Iron Works, as the chairman. "Could your foundry have used $600,000 more profit during the past six years?" If the answer is "yes," then you should take a close look at the *"Work Simplification Program"* that netted this remarkable result for Texas Foundries, Inc., Lufkin, Texas. **Jack Irish** of Texas Foundries described their successful program. Next speaker was an industrial psychologist, **Dr. E. C. Nevis**, Personnel Research & Development Corp. with the subject, *"A New Approach to Personnel Selection."* Tests are being given to evaluate job applicants, to improve use of present employees, and to improve job performance. Concluding speaker was **D. B. Fulton**, Northern Malleable Iron Co., telling the problems of *"Fulfilling Promises of the Sales Department."* He advised foundrymen to be especially careful in shipping only good castings because one bad one can spoil reputation of many good ones.

NON-FERROUS FOUNDERS' SOCIETY . . . disclosed details of a broad marketing program for the non-ferrous castings industry at a Management & Operating Conference, Jan. 30, at the Indianapolis Athletic Club, Indianapolis. N.F.F.S. president, P. E. Lankford, treasurer, East Birmingham Bronze Foundry Co., Birmingham, Ala., reported on work of three Society committees—marketing, technical and cost—which are participating in the N.F.F.S. marketing program.

"Quality standards, dimensional tolerances and surface finishes under study by the technical committee will lead to the promulgation of a set of casting standards," Lankford predicted. "These will help non-ferrous founders and their customers reach agreement on quality."

DUCTILE IRON SOCIETY . . . formulated by-laws at an organizational meeting held in Cleveland February 9. R. S. Thompson, H. P. Deuscher Co., Hamilton, Ohio, presided at the sessions at which by-laws were drawn up for approval of the membership of 51 foundries in the U.S. and Canada. Assisting in the organizational meeting was James H. Lansing, castings consultant, Shaker Heights, Ohio, who serves the new group as consultive executive secretary. A general meeting of the organization will be held in the immediate future.

AIRCRAFT CASTINGS ASSOCIATION . . . seven foundries have formed this new group to promote increased use of ferrous castings in the aircraft, missile and related industries. A. M. Slichter, Pacific Alloy Engineering Corp., San Diego, Calif., has been elected first president of the organization which will headquarter in Los Angeles. Member firms are: Electric Steel Foundry Co., General Metals Corp., Hanford Foundry Co., Lebanon Steel Foundry, Pacific Alloy Engineering Corp., Stanley Foundries, Inc., and Symington-Gould Div., Symington Wayne Corp. Corp.

FOUNDRY EDUCATIONAL FOUNDATION . . . Board of Awards has announced five F.E.F.-Wheelabrator Fellowship winners for 1959. The fellowships, valued at $1500 each, were awarded on basis of outstanding academic achievement, interest in the cast metals industry, leadership and personality characteristics and professional potential. Winners are:

- C. A. Rowe, Coraopolis, Pa., studying metallurgical engineering at Mas-

Continued on page 156

OLDEST KNOWN DIETERT-DETROIT SAND STRENGTH UNIT

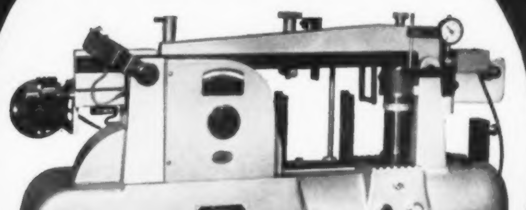
Dietert-Detroit Serial No. 2048 strength machine tested green compression and shear strength only

RETIRED

after **30** *years*

Harry W. Dietert Co. recently conducted a contest to find the oldest Dietert-Detroit Sand Strength Machine in daily use. 157 foundries reported on a total of 164 old-timers in the 20 to 30 year life range. The unit shown at left bears serial No. 2048. It was sold in 1928, was discovered at Clio Foundry, Clio, Michigan, in daily use, and going strong—attesting to the strength, durability and accuracy of foundry testing equipment bearing the Dietert name.

MODEL 405
DIETERT-DETROIT
Universal Sand Strength Machine



Greater capacity, sensitivity, and accuracy than any other instrument of its kind.

REPLACED

in **30** *minutes*

Harry W. Dietert Co. reserved the right to retire the 30-year unit, while Clio Foundry received as first prize a new Model 405 Dietert-Detroit Universal Sand Strength Machine. Operating instructions were transmitted in 30 minutes. *Write now for details.*

tests...

MOLDING SANDS
(a) Green Compression
(b) Dry Compression
(c) Green Shear
(d) Dry Shear
(e) Green Tensile
(f) Deformation
(g) Toughness

CORE SANDS
(a) Green Compression
(b) Baked Tensile
(c) Baked Transverse
(d) Baked Transverse Deflection

SHELLS
(a) Tensile Strength
(b) Transverse Strength

HARRY W. DIETERT CO.

9330 Roselawn, Detroit 4, Mich.

Gentlemen:

Send me facts on the No. 405 Dietert-Detroit Universal Sand Strength Machine.

Name____________________

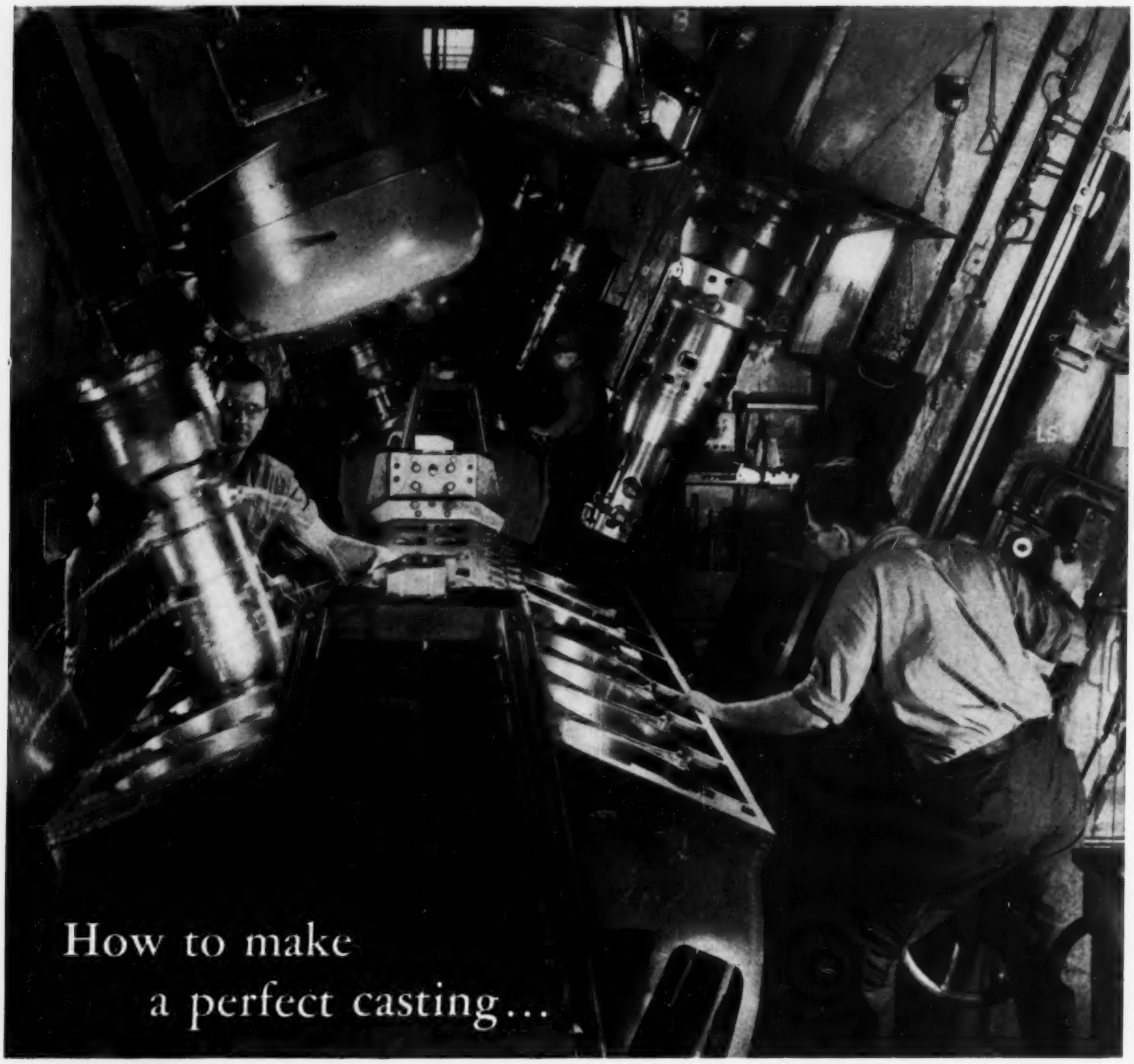
Title____________________

Company____________________

Address____________________

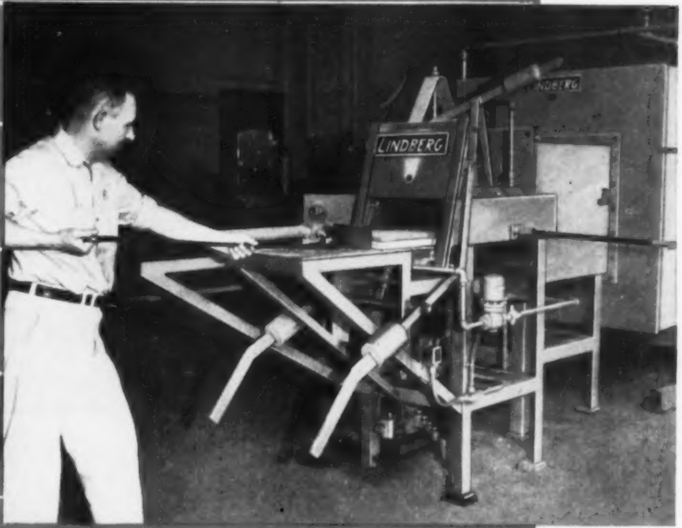
City__________ Zone_____ State__________

Circle No. 184, Page 167-168


How to make
a perfect casting...

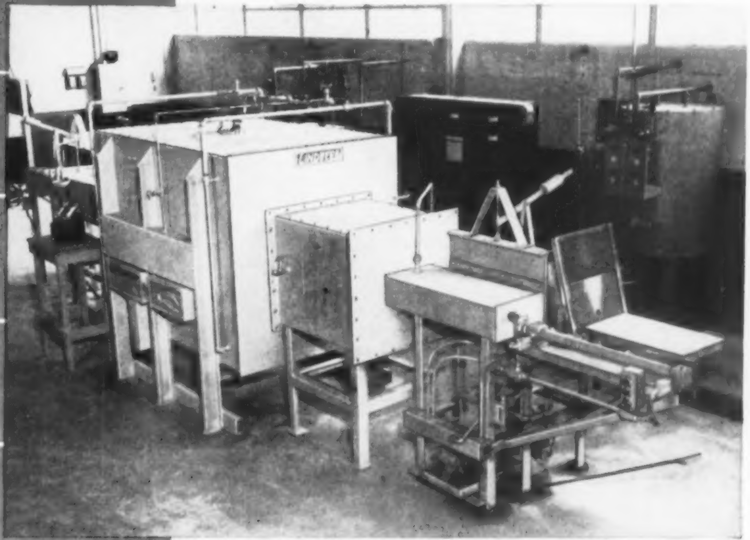
If your production needs call for Sintering call on Lindberg for just the right Furnace

As it does in all types of industrial heating equipment; Lindberg provides a complete line of sintering and brazing furnaces. Here is one of our latest:



A new Lindberg development, this Molybdenum Element Atmosphere Pusher Furnace is designed with high temperature refractories suitable for low dew point without need for a muffle. It is now being used for sintering stainless steel compacts in hydrogen or dissociated ammonia. Ammonia dissociator and control panels are shown at the right of the furnace below. In this installation hydrogen supply cylinders are located outside the building. Furnace provides side loading and discharge ports with purging chambers. Work trays, ceramic slabs or molybdenum boats, move through the furnace by hydraulic pusher. If you have a sintering or brazing problem why not talk it over with Lindberg. Just get in touch with your nearest Lindberg Field Representative or write us direct. Lindberg Engineering Company, 2440 West Hubbard Street, Chicago 12, Illinois.

Type MOP-12367-A60C Molybdenum Element Atmosphere Pusher Furnace. Maximum Temperature 3000° F. 60 KW input. 12" wide, 30" long, 7" high. 60" cooling chamber, 36" long preheat chamber.



Look up Lindberg, Booth 2, at Metal Powder Show in Philadelphia

LINDBERG heat for industry

Circle No. 185, Page 167-168

for the asking

Build an idea-file for improvement and profit. The post-free cards on the last page will bring more information . . .

Technical translations . . . of Russian and other technical material are included in new government publication. For more information about this service, use circle number below. *Office of Technical Services, United States Department of Commerce.*
Circle No. 37, Page 167-168

Alloying ingredients . . . for production of alloyed steels and irons described in booklet. *Alloy Metal Products, Inc.*
Circle No. 38, Page 167-168

Iron and steel scrap . . . fact sheet in folder form answers many questions about scrap. *Institute of Scrap Iron & Steel Inc., Committee on Bankability.*
Circle No. 39, Page 167-168

Cutting and grinding . . . trends and advances reviewed in new periodical which includes metalcasting information. *Simonds Worden White Co.*
Circle No. 40, Page 167-168

Melting guide . . . helps select immersion heaters, controls and melting pots for solder, babbitt, etc. *General Electric Co.*
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Circle No. 42, Page 167-168

Core processes . . . reprint, six pp, discusses four major core making processes with a comparison of advantages and disadvantages of each. *Archer-Daniels-Midland Co.*
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Sand recovery . . . system, pneumatic, outlined in 4-p bulletin. *National Engineering Co.*
Circle No. 44, Page 167-168

Casting alloys . . . development and standardization in the United States is subject of 16-p booklet. Use circle number below. *WaiMet Alloys Co.*
Circle No. 45, Page 167-168

Electric vibrator . . . for vibrating foundry material in bins, hoppers and chutes covered in catalog. *Syntron Co.*
Circle No. 46, Page 167-168

Casting alloy . . . high strength, ductile, outlined as to melting, casting and heat treating. Specifications and properties listed. *Kaiser Aluminum & Chemical Sales, Inc.*
Circle No. 47, Page 167-168

Machining manual . . . 22-pp, contains guide for machine feeds and speed, includes quantity-weight slide rule calculator, and other basic information. *Kaiser Aluminum & Chemical Sales, Inc.*
Circle No. 48, Page 167-168

Electric furnaces . . . fully automatic laboratory models featured in data sheet. *Thermo Electric Mfg. Co.*
Circle No. 49, Page 167-168

Refractory binder . . . will set at temperatures above 150 C. Discussed in brochure. *Philadelphia Quartz Co.*
Circle No. 50, Page 167-168

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Cranes . . . designed to provide big-crane performance at reportedly lower price described in brochure. Hoist, trolley and bridge types. *Whiting Corp.*
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Japanese foundry equipment . . . well illustrated and described in catalog. Written in English. *Kubota Seisakusho, Ltd.*
Circle No. 53, Page 167-168

Heat-resistant metals . . . reportedly 3 to 4 times stronger than conventional types are discussed by scientists. *Denver Research Institute.*
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Wall chart . . . lists decimal equivalents of fractions of an inch—1/64 to 1 in. Use the Reader Service card, last page, for your free chart. *Ohio Seamless Tube Div., Copperweld Steel Co.*
Circle No. 55, Page 167-168

Plant location . . . factors for consideration by small industry offered in government periodical. *Small Business Administration.*
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Corrosion-resistant alloy . . . data presented in 16-p technical report. *Haynes Stellite Co.*
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Sand muller . . . features rubber mulling tires and liner. Use number below for illustrated, 24-p brochure of diagrams, specs and applications. *Beardsley & Piper, Div. Pettibone Mulliken Corp.*
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Cupola equipment . . . which officials claim result in substantial coke savings, described in 4-p bulletin. *Brown Thermal Development Co.*
Circle No. 59, Page 167-168

Shot blast liners . . . for long wear in shot blast machines discussed in 12-p bulletin. *Latrobe Steel Co.*
Circle No. 60, Page 167-168

Pearlitic malleable handbook . . . 76 pp, serves as ready reference on latest information and data. A copy is yours *if* you are a design engineer or can use this engineering data in your work. *Malleable Research and Development Foundation.*
Circle No. 61, Page 167-168

Motor-generator sets . . . vertical, high frequency. Bulletin lists ratings and dimensions, features. *General Electric Co.*
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Vacuum furnaces . . . for induction melting, capacities 17 to 50 lb, covered in data sheet. *F. J. Stokes Corp.*
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Circle No. 70, Page 167-168

Wet magnetic particle . . . inspection unit designed for production testing of small ferrous parts. *Magnaflux Corp.*
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Power filing machine . . . detailed in bulletin. *Newage Industries, Inc.*
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Layout machine . . . allowing layout

work from five sides; inside surface checks with one positioning of casting. Use circle number for literature. *Portage Double Quick, Inc.*
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Conveyors, feeders . . . and vibrating equipment included in 68-p catalog which is pocket-size condensation of company's large catalog. *Syntron Co.*
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Abrasive cleaning . . . ideas including blast cleaning, finishing and shot peening offered in 28-p brochure. *Wheelabrator Corp.*
Circle No. 76, Page 167-168

Wall chart . . . giving designations and specifications for non-ferrous alloys. *Non-Ferrous Founders' Society.*
Circle No. 77, Page 167-168

Sythetic resins . . . (powdered phenol-formaldehyde) for foundry shell molding (dump box) applications covered in technical bulletin. *Reichhold Chemicals, Inc.*
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Electron beam furnace . . . for refining and casting of special metals fully explained in brochure. *Stauffer-Temescal Co.*
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Welding carbon products . . . electrodes, plates, rods and paste described in bulletin. *Arcair Co.*
Circle No. 83, Page 167-168

Glass fabrics . . . for dust and fume control described in brochure. *Coast Mfg. & Supply Co.*
Circle No. 84, Page 167-168

Vibrating feeder . . . for controlled feeding of bulk materials covered in leaflet. *Link-Belt Co.*
Circle No. 85, Page 167-168

Index . . . to 1958 Modern Castings. Lists the subjects, titles and the authors of all important information published during last year. *American Foundrymen's Society.*
Circle No. 86, Page 167-168

if you can't wait

for your mailman to come, you're no different than other smart foundrymen who use our reader service card, last page.

Training courses . . . pertinent to every type of metalcasting work are offered by the AFS Training and Research Institute. For free brochure covering all courses offered, circle number below on Reader Service card, last page. *American Foundrymen's Society.*
Circle No. 87, Page 167-168

Safety lock-out . . . to prevent power source from being thrown-on detailed in brochure. *Dayton Rogers Mfg. Co.*
Circle No. 88, Page 167-168

Portable hardness tester . . . capacity of 12-in. dia or thickness for testing castings anywhere. *Riehle Testing Machines.*
Circle No. 89, Page 167-168

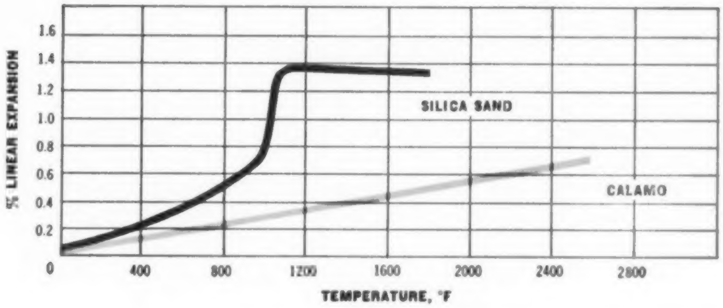
Metalcasting technology . . . experts have written many books and manuals which *Continued on page 148*

Harbison-Walker

REFRACTORY MOLD MATERIALS

for metal casting

EXPANSION CURVES, SILICA SAND VS CALAMO



Calamo for Investment Molds

CALAMO, one of the extensively used Harbison-Walker products for molding is an alumina-silica refractory of optimum sizings for various molding mixtures. Its fusion point is 100°F. higher than that of normal silica sand mixes.

The chart above shows the exceedingly desirable expansion curve of CALAMO as compared with that of silica sand.

CALAMO, used as the major constituent of precision casting investment mixes, improves the dimensional constancy of the molds, makes them stronger and more resistant to erosion by metal flow. Investment costs are measurably reduced because an appreciably lesser amount of bonding agent is needed. This is attributable to the very desirable particle sizing and the equiaxed, dense grains of CALAMO.

CALAMO, used alone or as the major part of conventional dry sand molding mixes in rammed or in slinger-placed sand molds, provides not only the very desirable low thermal expansion characteristics particularly suited for precision casting but also provides the required refractoriness for metals and alloys which are melted at unusually high temperatures.

H-W Forsterite Grains for Shell Molds

Forsterite grain is highly refractory magnesium silicate possessing physical properties which make it especially suited for resin-bonded shell molding. Its specific heat, thermal conductivity, high temperature stability and uniform thermal expansion —all contribute to its excellent performance.

As the result of the optimum chilling effect of forsterite grain, sufficient strength develops in the skin of the steel casting to resist outside gas pressure as well as inside ferrostatic pressure, and a smooth casting surface is assured.

H-W FORSTERITE GRAINS are supplied in controlled sizings best suited for securing the most satisfactory shell molded casting surfaces.

H-W FORSTERITE FLOUR is furnished for use as an additive to the H-W FORSTERITE GRAINS and resin mix to provide for the ultimate in surface smoothness, particularly of castings with heavy sections.

Write us for information regarding these and other Harbison-Walker products —mold wash materials—ceramic molding media—mold sand bonding clays.

HARBISON-WALKER REFRACTORIES COMPANY

AND SUBSIDIARIES GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA

World's Most Complete Refractories Service

Circle No. 192, Page 167-168

casting through the ages

for the asking

Continued from page 134

are available through AFS. A complete, classified list is yours when you use the circle number below. *American Foundrymen's Society.*

Circle No. 90, Page 167-168

Tape recordings . . . of technical talks on many facets of the metalcastings industry are available from AFS. Circle number below for complete listing. *American Foundrymen's Society.*

Circle No. 91, Page 167-168

free reprints

■ The following reprints of feature articles which appeared in MODERN CASTINGS are available to you free of charge. Use the Reader Service card, last page.

Modernization . . . used to achieve high productivity at iron works outlined in reprint from MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 92, Page 167-168

Sodium silicates . . . for the CO_2 process discussed in 9-p report on research by the U. S. Naval Research Laboratory, Washington, D. C. *American Foundrymen's Society.*

Circle No. 93, Page 167-168

CO_2 cores . . . used in malleable foundry reported on in technical article reprinted from MODERN CASTINGS. Use the Reader Service card, last page, for your free reprint. *American Foundrymen's Society.*

Circle No. 94, Page 167-168

Controlled heat transfer . . . rate is basic in new mold process discussed in technical report reprinted from MODERN CASTINGS. *American Foundrymen's Society.*

Circle No. 95, Page 167-168

training films

■ The following list of motion pictures and film strips will prove useful in educating your personnel to better perform their jobs. Circle the appropriate number on the Reader Service Card, last page, for complete information regarding these films. Items indicate whether films are available free of charge, by rental or by purchase only.

Steel shot manufacture . . . depicted in 16 mm film covering operations from scrap selection to packaging. 25 min, color, sound. *Wheelabrator Corp.*

Circle No. 96, Page 167-168

Titanium castings . . . film depicts operations involved in their fabrication. Sound, color, 16 mm, free; running time is 18 min. *Frankford Arsenal.*

Circle No. 97, Page 167-168

Ultrasonic inspection . . . film describes development, theory and application of device for non-destructive testing of metals and other materials. *Sperry Products, Inc.*

Circle No. 98, Page 167-168

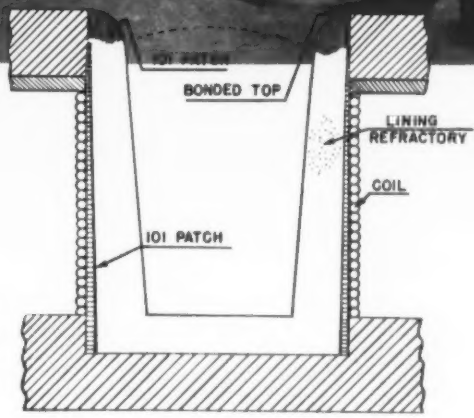
Circle No. 149, Page 167-168

Circle No. 197, Page 167-168

Circle No. 198, Page 167-168

USE

TASIL NO. 101 PATCH



for high frequency induction furnaces

TASIL (Taylor Sillimanite) No. 101 Patch is widely used by operators of high frequency induction furnaces for coating of the inner surface of the water-cooled, primary coil. When air dried, this coating will:

1. **Protect the coil when the crucible is being rammed in place.**
2. **Protect the coil from damage in the event of a leakage of metal through the lining proper.**

Properties which qualify TASIL No. 101 Patch for this service are: *high di-electric strength . . . smooth working properties . . . softening point above 3200° F. . . . negligible shrinkage or expansion . . . can be used with either an acid or basic lining.*

There is a complete line of TASIL (mullite), TAYCOR (corundum-base) and TAYLOR ZIRCON Ramming Mixes and Cements for every metallurgical need. Write for recommendations to cover your melting requirements.

TAYLOR ZIRCON · TAYLOR SILLIMANITE

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Circle No. 200, Page 167-168

Organic Cold Setting Binders

E. S. Valentine
Reichhold Chemicals, Inc., White Plains, N. Y.

■ Organic cold setting binders are principally composed of specialized drying oils activated by oxygen bearing chemicals. All of these materials are dependent on the absorption of oxygen, either from the atmostphere or from an oxygen-bearing chemical to develop their initial strength.

OXYGEN SETS BINDER After mixing sand and binder, the oxygen from the atmosphere and from the activator begin to be absorbed chemically by the oils. A film of a reasonably rigid nature is formed to cement the sand grains together.

QUICK STRENGTH The green strength ultimately arrives at approximately 50-90 lb psi. The cycle is completed when the core cures to completion by further oxidation and polymerization in an oven.

ACCURACY Because strength is developed and the sand mass is hardened against the pattern or core box, almost exact duplication of the dimensions and details of core box or pattern are obtained.

Since the sand is free flowing and possesses virtually no green strength, it is easy to fill the core box or flask with little if any ramming.

HARDEN IN CORE BOX In heavy core work you can use a two-piece box, making the core whole instead of making a core in halves, since the core will attain very high strengths in the box. Thus jigging, sanding, pasting and mudding of joints can be eliminated.

QUICK BAKING Because no moisture is present and part of the curing process has already taken place at room temperature, cores made by this process bake out very rapidly in the oven.

Since the entire batch sets simultaneously whether the sand is in boxes or in the wheelbarrow, there must be sufficient scheduling organization so that all of the sand can be utilized without excessive waste.

NEED 15 MINUTES The core box or pattern must necessarily be tied up as long as it takes the sand to set. This means a period of a minimum of 15 minutes to several hours. Therefore this type of process does not lend itself to use in places where there are very few duplicate core boxes and where high speed production is expected.

BEST APPLICATIONS Where heavy, intricate cores are made on a jobbing basis, the cold-setting binder would seem to offer many advantages.

Editor's Note: *This article contains highlights excerpted from a talk by E. S. Valentine presented at the* 1958 *AFS Northwest Regional Conference.*

foundry trade news

Continued from page 138

sachusetts Institute of Technology. He has held an F.E.F. scholarship since 1957.

▪ J. H. Steele, Jr., Blacksburg, Va., studying metallurgical engineering at Virginia Polytechnic Institute. He has been granted three state scholarships and an A.S.M. award.

▪ R. G. Liptai, St. Louis, whose course of study is mechanical engineering at Missouri School of Mines, is a member, AFS Rolla Student Chapter.

▪ E. J. Poirier, Medford, Mass., is studying chemical engineering at Northeastern University. Under the Wheelabrator Fellowship, he will study metallurgical engineering at the graduate level, Massachusetts Institute of Technology. He is a member, M.I.T. Student Chapter of AFS.

▪ T. S. Piwonka, Cleveland, will graduate in June, 1959, from Case Institute of Technology. He will continue work on his Master's degree in metallurgy. Piwonka held the Leonard Case honor scholarship during his four years at the Institute.

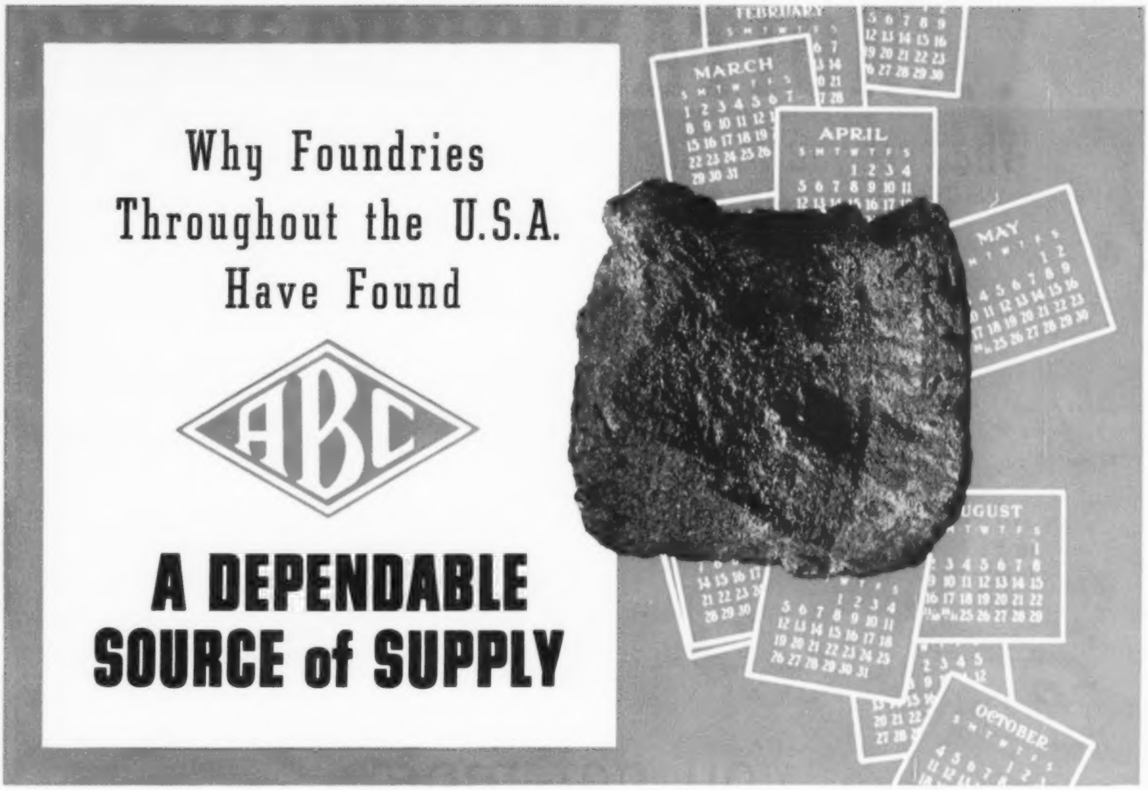
Eight similar Wheelabrator awards were granted in 1958.

CAST BRONZE BEARING INSTITUTE . . . discussed a radically simplified approach to design, analysis and requirements for cast bronze sleeve bearings during a meeting to review the first draft of their new technical manual. The meeting was held Jan. 29, at the Indianapolis Athletic Club, Indianapolis.

Friction & Lubrication Section, Franklin Institute, Philadelphia, prepared the manual under C.B.B.I. sponsorship. Harry Rippel, Franklin Institute project engineer, pointed out that the manual fulfills a design and application need in full-film, complete boundary, and mixed film sleeve bearing applications.

McCarthy Foundry Co. . . . Chicago, has been purchased by Accurate Industrial District. In addition to the casting production facilities 12 acres of land were acquired for improved manufacturing. Currently largest division of Accurate Industrial is Accurate Perforating Co.

Kolcast Industries . . . has been licensed to produce precision investment castings for unusual temperature and corrosion applications in "SR" steels. Uniworld Research Corp. of America holds the patents on the alloys which will be cast by the Minerva, Ohio, investment caster.



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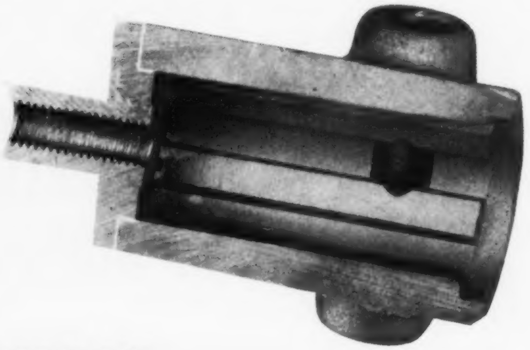

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These and other outstanding characteristics of standard and pearlitic Malleable castings provide the solution for today's design problems. No other metal offers so much at so low a cost.

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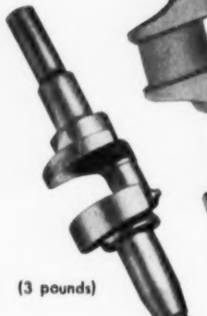

(3 pounds)

Engine Crankshafts

Malleable Founders Society

Union Commerce Building · Cleveland 14, Ohio

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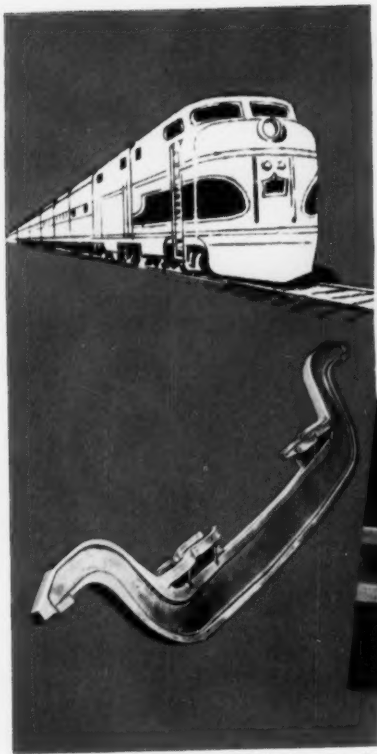
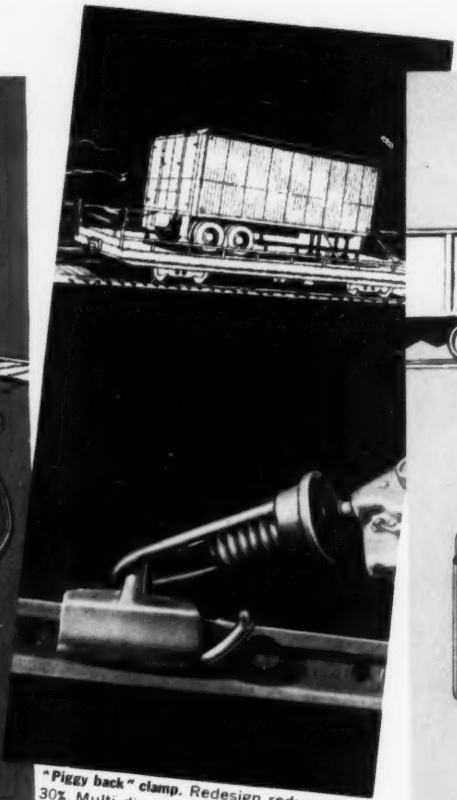
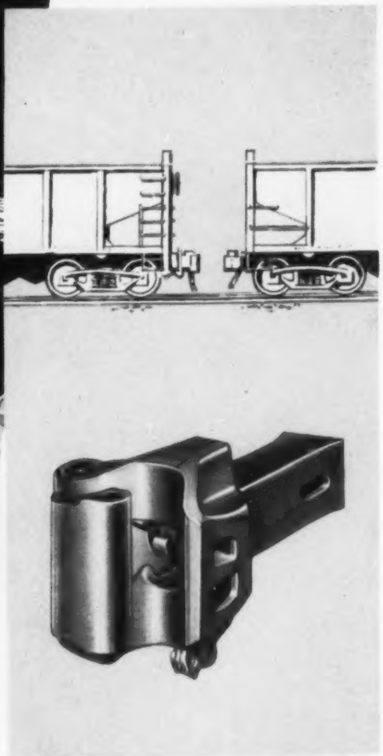


Diesel locomotive truck equalizer. Redesign to cast steel reduced weight 2,000 pounds per locomotive . . . made it stronger, more shock-resistant.



"Piggy back" clamp. Redesign reduced cost 30%. Multi-directional endurance — a basic steel casting property — lengthened life, reduced weight.



Couplers. Repeatedly subjected to tremendous impact forces, cast-to-size couplers give normal service life beyond 30 years. There are over 4,000,000 in use; they all mate perfectly.

Design

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Into Your Products . . . Use STEEL CASTINGS

On every locomotive, freight and passenger car, you'll see steel castings: side frames, one-piece underframes, bolsters, yokes, wheels, hopper doors, brake beams, single-unit locomotive trucks, and *all* the couplers used in this country.

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Reference Chart of Steel Castings' Properties.
32-page booklet:
"Fatigue Properties of Cast and Comparable Wrought Steels".
Product Design Studies on steel castings for products you manufacture.

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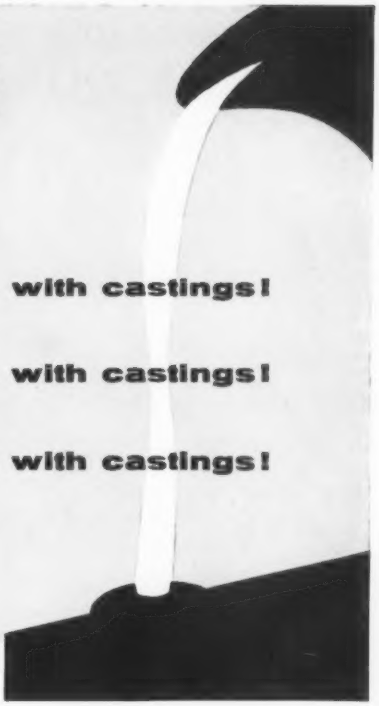
castings are wonderful!



What is the only way to make large metal parts of complex shape economically? . . . . with castings!

How can you make the most small parts at lowest cost—by the million, if you need to? . . . . . with castings!

What is the best way to make parts with smooth changes of stress flow? . . . . with castings!

THESE ARE THE FACTS AGGRESSIVE FOUNDRYMEN ARE TELLING, individually and together, through their societies—in the grey iron, nonferrous, malleable and steel fields.

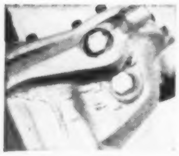
They add one more fact:

good design and consistent quality build more casting business

The buyer of castings requires only that his standards for reliable service be met. **THEORETICAL PERFECTION is needlessly wasteful to him . . . and costly to you.**

we can help you make better castings—cheaper!

In scores of the best known foundries across the country Magnaflux Test Methods are now considered essential to reliable lowest cost casting production. If you are not now using them, we suggest especially that you investigate:

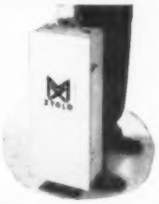


1. STRESSCOAT

The Magnaflux stress analysis tool that shows where high stresses occur—*during your design or pilot runs.* Shows whether stresses are detrimental or harmless. Leads to easy design correction.

2. MAGNAFLUX-MAGNAGLO

Magnaflux Magnetic Particle Inspection Methods that show *which* cracks or defects are significant and which are within the range of safe acceptance and good service. Test pilot castings also, for best set-up! ALSO: Magnaglo automatic for volume testing.



3. ZYGLO

Provides the same testing benefits for nonferrous casting control, pilot castings, etc. Starts as low as $125 with new ZA-43 Zyglo Kit shown here.

Also eddy current instruments to control hardness, heat-treat, etc., and sort mixed alloy lots.

When you use these MX test methods—*with assurance*—you can sell more castings, to more people—for more uses. This, of course, means bigger markets, for you, *from now on!*

For the evidence, ask any foundry that has adopted the "Magnaflux Plan of Casting Control." Or ask a Magnaflux Engineer to outline it to you.

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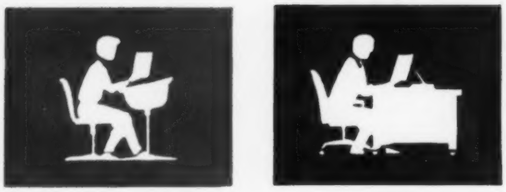

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classified advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . 25c per word, 30 words ($7.50) minimum, prepaid.

Positions Wanted . . 10c per word, 30 words ($3.00) minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 additional words.

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Experience in Gray Iron Foundry, and all phases of sand conditioning. Good opportunity. Relocate Middlewest.

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when you need SUPERVISORY or TECHNICAL men why not consult a man with actual foundry experience plus 15 years in finding and placing FOUNDRY PERSONNEL.

Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

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Experienced in foundry operations as well as general industry. Cap- of industrial engineering division of able of taking over management ACME member consulting firm. Degree necessary. Age 35-45. Send complete details and include recent photograph. All replies held in confidence. **Box F-135, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

AGENTS WANTED: Distributors or manufacturer's Agents. Several choice territories available to experienced foundry equipment salesmen or agencies interested in selling the world-Famous **HANSBERG CORE SHOOTER.** Hansberg is the most successful core making machine of the last ten years and is better than competitively priced. More models than any other manufacturer. New bench and floor models include Semi- & Fully-Automatics. Combination Shooter-Gassers, Roll-Over-Strippers, Vacuum & Pressure CO_2 Gassers. **Write to HANSBERG SHOOTERS, INCORPORATED, P.O. Box 729, Evanston, Illinois.**

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Experienced on layout of all types of foundry equipment, material handling and material flows. Send complete details on work history, education and family status. Include recent protograph. All replies confidential. **Box F-140, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

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with good training in metallurgy, experience in gating, risering, pouring and molding copper-base alloys and who has supervisory qualities to assume direction of sand and centrifugal foundry in Indiana. Send complete details, education, experience, health, weight, salary required. **Address Box F-151, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

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ASSISTANT PLANT MANAGER — 36 years old. Desires position with an established non-ferrous foundry. Experience in Metallurgy, Lab-Supervision, gating and all phases of sand, permanent mold and plaster mold operations. Some semi-investment experience. Presently employed. **Box F-149, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRY FOREMAN — two years experience in automated non-ferrous foundry. Young graduate engineer desires position with opportunity to work in all phases of foundry work. Particularly interested in technical side. Prefer to locate in Houston area but am open to any place in Southwest. **Box F-150, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines.**

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BACK VOLUMES — Wanted to buy for cash of foundrymen, TRANSACTIONS American Foundrymen's Society and other scientific technical Journals, **A. S. ASHLEY 27 E. 21, N. Y. 10, N. Y.**

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Savings of fuel dollars and more flexible production scheduling are only two of Dexocor's advantages. Among its other features are: faster mulling . . . low gas generation . . . excellent green strength . . . high baked strength . . . uniform density . . . easy shake-out . . . ready collapsibility.

Whether you make small or large castings, simple or intricate, you will profit by the properties of Dexocor. One foundry now uses it in 19 different sand and core mixes!

For the full facts on this amazing new binder and technical assistance in adapting it to your special needs, contact our nearest sales office or write direct.

*Source on request

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here's how

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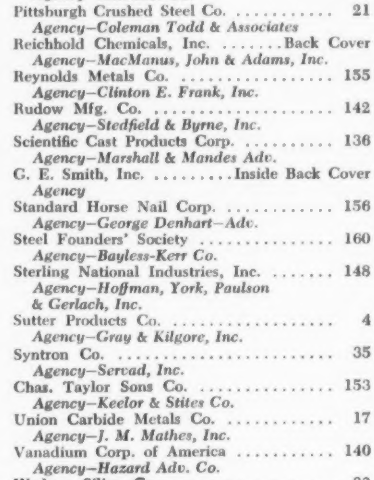

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Golf & Wolf Roads

Des Plaines, Illinois

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Name ______________________ Title ______________________

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1	13	25	37	49	61	73	85	97	109	121	133	145	157	169	181	193	205	217	229
2	14	26	38	50	62	74	86	98	110	122	134	146	158	170	182	194	206	218	230
3	15	27	39	51	63	75	87	99	111	123	135	147	159	171	183	195	207	219	231
4	16	28	40	52	64	76	88	100	112	124	136	148	160	172	184	196	208	220	232
5	17	29	41	53	65	77	89	101	113	125	137	149	161	173	185	197	209	221	233
6	18	30	42	54	66	78	90	102	114	126	138	150	162	174	186	198	210	222	234
7	19	31	43	55	67	79	91	103	115	127	139	151	163	175	187	199	211	223	235
8	20	32	44	56	68	80	92	104	116	128	140	152	164	176	188	200	212	224	236
9	21	33	45	57	69	81	93	105	117	129	141	153	165	177	189	201	213	225	237
10	22	34	46	58	70	82	94	106	118	130	142	154	166	178	190	202	214	226	238
11	23	35	47	59	71	83	95	107	119	131	143	155	167	179	191	203	215	227	239
12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240

Void after October 1, 1959